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ON AN INFINITE UNIVERSE.*

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In 1720 Halley published a paper in the *The Philosophical Transactions* in which he stated, that since the light diminished at a more rapid rate than the interval between the stars, space would not be equally illuminated if the stars were infinite in number. And secondly, that at a certain distance the stars became invisible.

On the contrary, Chesaux, a Swiss astronomer and speculative writer, asserted "that the light of an infinite number of shining bodies would cause the heavens to appear everywhere equally illuminated with the Sun." And on this ground he affirmed that the universe must be finite unless light is lost in space.

The assertion of Chesaux was apparently regarded as an axiom, and has continued to the present day as the generally accepted doctrine in Astronomy.

I am not informed on what grounds Chesaux based his statement but a century later Olbers gave his support to the idea in a mathematical paper, published in 1826.

The visible universe is composed of a mass of heterogeneous matter, having different degrees of luminosity. The amount of dark matter in space is not definitely known, but it is perhaps the general opinion that it may be equal to that which emits light.

The light emitted from the bodies in space may be said to vary in intensity between zero and that given by the surface of our Sun or even greater. In order, therefore, that the heavens should appear to be of uniform brightness, the light everywhere must be equal in intensity to that at the surface of the most brilliant star.

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The statement by Chesaux "equally illuminated with the Sun", I understand, means that the heavens everywhere would appear as bright as the surface of the Sun—viz: a light sheet of the intensity of the Sun's surface, as seen from the Earth.

That the light given by an infinite universe should be exactly equal to the light of our Sun at just 93 millions of miles from that body seems to me so improbable that there is good ground to think that some fallacy is involved in the argument which led to such a conclusion.

The illumination of the heavens by the Sun, or a light sheet, as viewed from the Earth, is not constant during the year, and varies very materially in the solar system.

To an eye placed on Mercury there would be six times as much light and on Neptune only $\frac{1}{900}$ of the light as at the Earth. And we may imagine a planet at about $\frac{1}{11}$ of the distance to the nearest fixed star, where the illumination of the heavens by our Sun would be the same as that furnished by the stars. And we may further imagine an eye placed in space half way to the nearest fixed star where the light would always be the same, and our Sun would appear as a bright star. In other words, the illumination of the heavens by our Sun, or any other sun, would depend on the distance of the eye from the illuminating body and the nature of the illuminating surface.

To an eye placed on a planet revolving around a red star, the heavens would be illuminated with red light.

In the early part of the last century, in order to overcome the objections to the theory of an infinite universe, Struve formulated a theory of the extinction of light passing through space, based on the observations of Sir William Herschel. Sir John Herschel has shown that his father's observations had been misinterpreted. Struve's theory is sometimes quoted but has not been generally accepted by astronomers.

Now if there were an infinite number of suns, there would be an infinite amount of light, but this infinite amount of light would be spread through an infinite volume of space.

From this proposition one cannot determine the intensity of the illumination of space, or whether it is equal everywhere. The illumination would obviously be a function of the brightness of the shining bodies and the interval which separated them.

Since we cannot reason directly about infinity, we may per-

haps get some information by starting with a finite universe and moving towards infinity.

Suppose we start our universe with a small number, viz: four stars, and for the sake of simplicity, regard them equal in brightness. Between these four stars there will be a point of minimum illumination at the point where sums of the squares of the distances is a maximum.

As other stars are added this point of minimum illumination will be continually shifted. When we reach infinity, however, there will be no center of minimum illumination and this is all we can infer directly regarding infinity.

Returning now to our four stars. I assume that the illumination at the minimum point is immeasurably less than at the surface of any particular star and this is true whatever the number of stars, even if they be infinite.

If the light at the surface of a star is taken as unity, the light received from any other star at that point, would be $\frac{1}{d^2}$. The light received at our initial point from an infinite number of stars, whose distance is continually increasing, would therefore be the sum of an infinite decreasing series, $\frac{1}{a^2} + \frac{1}{b^2} +$ etc., and the sum of this infinite series can never be equal to unity, provided the ratio between successive terms is greater than the limiting value. If this be true, each star would retain its autonomy and remain a star, and hence space would not be equally illuminated.

From what we know regarding the distance of the stars, the limiting value in the above infinite series is immeasurably less than the real value.

The total light of the visible heavens is stated to be about $\frac{1}{27{,}000{,}000}$ of the light of the Sun at 93 millions of miles from that luminary. Assuming that the law of the inverse square of the distance is true to within ½ a million miles of the Sun's surface, and for the remaining distance varies directly as the distance, the ratio of the light at one mile from the surface of the Sun to the rest of the universe is as 1 to 10^{-17}. Referred to the same point, the first term in our infinite series is approximately 10^{-20} and the last term zero.

If we assume that 200 millions of stars are within our reach by means of the photographic plate, it follows that the sum of the first 200 million terms in our infinite series is equal only to

10^{-17} which is strong preservative evidence that the total sum of the above series would never equal unity.

If we take into account the opaque matter in space, every alternate term in the above series would be zero, and besides, we would have an equal number of negative terms, the opaque matter intercepting the light passing from one region of space to another.

That the stars would remain individual stars, however great their number, may be inferred in a simpler manner.

An infinite universe may be made up of an infinite number of finite parts. Now if the stars retain their autonomy and remain separate stars in each of these parts, the same must be true when the parts are joined together to form a unit, since no quantity can be greater than the sum of its parts. Or the proposition may be stated in this way:

In a limited universe, no one would call in question the assertion that each star would retain its autonomy and remain a star, however great the number of the stars and however great the distance. Now if this condition prevailed until we reached the finite limit, say for illustration, to within one mile of infinity, it would be unreasonable to conclude that on the completion of the last mile all the stars would be swallowed up and obliterated in a flood of light

Second. Is Halley's idea regarding the invisibility of stars at a certain distance in any degree confirmed by modern science? The human eye utilizes as light but in a small fraction of the light vibrations in the solar spectrum.

The photographic plate, however, can record, in both ends of the spectrum, vibrations which are no longer light to the human eye. It is said that we can see about 100 millions of stars with our present optical appliances, and photograph about 100 millions more which we cannot see.

And I presume everyone will agree to the proposition that there are stars so remote that the vibrations in the ether make no impression on the photographic plate.

The question naturally arises as to whether these remote stars add to the illumination of the space in which the observations are made.

Some years ago, I determined the actual time required for a standard candle to make a legible impression on various brands of photographic plates. I find the light of a stellar image impressed on a plate after four hours' exposure to be equal to $\frac{1}{3{,}000{,}000}$ of a standard candle at one foot distance.

And taking into account the difference of actinism between white and yellow light, we may conclude that it would require more than 30 millions of stars, requiring four hours' exposure, to be equal to one candle at one foot distance.

And since it is by no means certain that these feeble light waves are light to the human eye, I think we have strong grounds for assumption that the remote stars add but an infinitesimal amount to the illumination of the heavens.

The arguments in support of a finite universe, advanced by Olbers and more recently by Seeliger, 1895, in a paper on gravity, are based on certain assumptions and hence are necessarily of a speculative character.

In the article on Astronomy in the Encyclopedia Brittanica, the writer, after expressing his opinion that the universe is limited, offers the following argument to prove that it is finite. He assumes that there are three times as many stars of each succeeding magnitude than of the previous one—viz: three times as many 7ths as 6ths, etc., down to the 10th or 11th magnitude. Since the light between consecutive magnitudes is diminished 2.5 times and the number of stars increased by three, there would be an increase of light for each succeeding magnitude, which, if continued to infinity, would afford "a flood of light equal to the Sun."

If the universe was constructed on this plan, it follows from this increasing infinite series that the farther away the stars are removed from us the more light we would receive, which is contrary to reason and leads to an absurdity.

An infinite amount of light coming from an infinite distance would be zero. And hence the last term in the above increasing infinite series should be zero instead of the greatest possible.

However, the subject needs no discussion, since the researches of Kapteyn, on the distribution of stars in space, shows that the above assumption of a mean ratio of three was erroneous, as he finds a decrease in star density at the 9th magnitude. Hence the argument for a flood of light equal to the Sun becomes zero.

Kapteyn, I presume accepts the doctrine of a finite universe as would appear from the following consideration. He says the star density becomes less beyond the 9th magnitude, but as yet, little is known regarding the stellar distribution beyond the 12th magnitude. However, he makes the suggestion that the star density may become zero at a distance of 30,000 light years, which of course would be the limit of the universe.

Now with all due respect to the high authorities above quoted,

I would remark that if these are the best arguments which can be advanced in proof of a finite universe, the theory rests on a very weak foundation.

Since space is infinite in extent, it would be unreasonable to suppose that only a small portion was utilized to hold matter and all the rest left blank.

In conclusion, to my mind, the idea of a limited universe is of the same nature as entertained by early man, who on a flat earth, thought the sea-horizon was the limit of creation.

Evanston, Ill.

THOMAS DAVIS SIMONTON.

SEVERINUS J. CORRIGAN.

For Popular Astronomy.

Among all the natural sciences there is, probably, none that demands—and receives—from its students as much earnest and unselfish devotion as does astronomy in its divers branches, be the devotee a professional, practical astronomer holding an official and pecuniarily remunerated position as an instrumental worker in a well-equipped observatory; a theoretical astronomer laboring in the co-ordinate field of mathematical research in the profession, on the one hand, or on the other hand, an amateur—using that word in its strict sense—a true lover of the science, imbued with the joy of learning and of the persistent search for Truth for its own sake, laboring not only without pecuniary recompense but often at considerable personal expenditure of time and money, and whose only reward is the indescribable intellectual satisfaction—which surpasses the understanding of the major portion of mankind—that he derives from his studies, and the keen pleasure that he feels in imparting to others, either by tongue or pen, what he himself has learned, and beholding awakened in them a kindred enthusiam and love for the noble science.

To the latter order—although, had the fates so directed his course, his natural aptitude would have led him to distinction in the former—belonged the subject of this biographical sketch,

—Thomas Davis Simonton—who, at the city of St. Paul, Minnesota, on the 14th of last December, when nearly seven years above the scriptural limit of age, passed behind the veil that stretcheth beyond the stars, and is impenetrable by mortal vision, he having been a pioneer of that city not only in point of residence but also in its intellectual, civic and religious life —his work in these several fields having been characteristically unobtrusive, but none the less potent for good.

In both direct line and collateral connections Dr. Simonton—by which title he was generally known in this community—was of the best blood of the land, tracing his ancestry to that sturdy, strong-minded race, the Scotch-Irish, many of whom were early settlers in the state of Pennsylvania, his paternal grandfather —William Simonton—having come thither, as a boy, from the county Antrim, Ireland, in the the year 1765, at the solicitation of an uncle of the same surname, who had preceded him to this country. His was also a scholarly family that has furnished many members distinguished in the church, the law, medicine and the teaching profession and the halls of legislation, his father William Simonton, M. D., having been for many years the leading practicing physician in Dauphin County, Pennsylvania, and the region surrounding Harrisburg; County Auditor, 1823—1826 and—as a Whig—a representative in the 26th and 27th congresses, from 1838 to 1842. His maternal grandfather, an uncle on his father's side, two of his own brothers, and other relatives were ministers of the Presbyterian church—his youngest brother, now dead, having been a missionary of that denomination in Brazil. Another brother, John W. Simonton—who died in 1903 —was an eminent jurist and for years a presiding judge of the 12th Judicial District of Pennsylvania, at Harrisburg, while a fourth brother—James W.—was a professor of mathematics and and also modern languages and literature in Washington and Jefferson College, and is now a *professor emeritus* of that old and well-known institution of learning in western Pennsylvania. With such ancestry and immediate environment, the refined taste, intellectual bent, religious temperament and strong character that distinguished Thomas D.,—the fourth born of the five brothers—were both logical and natural sequences. He was born, January 25, 1831, on his father's farm in West Hanover township, Dauphin County, Pennsylvania, a dozen miles or so northeast of Harrisburg, and his boyhood was spent, as he himself has recorded, in the usual manner of country boys of those days: "Some work, more play in summer, and attendance upon

the district school in winter"—he also having been given for several years, a taste of real farm life, upon the family estate owned by his father, and operated under the direction of the latter. In the year 1847 the family removed to Harrisburg where, at the age of sixteen, the subject of this sketch entered upon an academical course, his studies apparently having been along classical lines, his reading including Horace in Latin, and Homer in Greek, and subsequently he spent a winter teaching school in central Pennsylvania. He afterwards received preliminary instruction in the profession that he was to follow in after life, under Dr. James Fleming a dental surgeon of Harrisburg, and for several years thereafter he pursued a thorough course of training in the Baltimore College of Dental Surgery from which he graduated in the year 1852 with the degree of D. D. S., practicing his profession in Harrisburg during the next five years. His particular interest in astronomical science—in so far as the writer has been able to learn by conversation with him—seems to have been awakened when he was quite young, and the great meteoric shower (Leonids) which startled the world on November 13 and 14, 1833, when he was only about three years old, was probably instrumental in this awakening, as he has often narrated to the writer his mother's vivid description of that wonderful phenomenon, famous in the annals of astronomy, and of which she had been a deeply interested and discriminating eye-witness. He often discussed with me, and others, certain scientific questions brought out by the details of this narration, in regard to peculiarities of the phenomenon, which had impressed him, and from which were drawn some apparently well-founded conclusions which, I think, he has set forth in some publication. One of the observed facts, which seemed to him very significant, was that in that copious shower of fiery, incandescent particles of matter some of the meteors were distinctly seen by the narrator to pass directly between the eye and buildings at a little distance away, belonging to the farm, and they caused no noise or sensible disturbance, and were not afterward upon evidence upon the ground toward which they had apparently fallen, the logical conclusion being that these meteors must have been particles of matter so extremely minute that they were probably dissipated as cosmic-dust just before reaching the surface of the earth, or upon reaching it, a conclusion perfectly in concordance with the best scientific opinion as to the small mass and dimensions of the components of all the known meteoric-showers—particularly of the Leonids

—and their particularly complete disintegration, or pulverization, as matter melted by the heat resulting from the friction of these particles, moving with a relative rate of nearly 41 miles per second—with the denser portions of the atmosphere near the surface of the earth.

He was thoroughly conversant with the works of the great German naturalist Alexander von Humboldt, and particularly with his observations and discussions of the aforesaid remarkable celestial phenomenon which seems to have been the *primum mobile* in the development of Dr. Simonton's deep interest in "meteoric astronomy" and all things pertaining to it, which he manifested during the greater portion of his long life, and which led him, when occasion demanded, to write in the daily press and other publications, authoritatively, interestingly and instructively concerning this subject, for the information of the reading public.

But the first evidence of his well-defined interest in, and extensive knowledge of, general astronomy and correlated subjects, was manifested in the year 1857 when he published (Philadelphia, Lindsay & Blakiston, 1857) an admirable translation into English from the German, of a work that had for several years, attracted much attention in religio-scientific circles both in this country and in Europe, the title of this book being "The Bible and Astronomy," it embodying an exposition of biblical cosmology and its relation to natural science, its author being an eminent scholar and theologian, John Henry Kurtz, D. D., Professor of Church History in the University of Dorpat, Russia, and an author of other works. Dr. Simonton's "labor of love" in this connection was his translation into English of the "third improved edition" of this book, and well he performed the task displaying therein not only a scholarly intimacy with the German language, but also a positive genius for smoothing out the complicated idioms of that tongue, and converting them into concise and elegant, clear and forceful English phraseology without sacrificing any of the substance or spirit of the original —his task also involving a thorough knowledge of all the fundamental facts and concepts of modern astronomical science. Both the original work and the translation thereof were, at the time of publication, widely and favorably commented upon in the secular and religious press, and even after the lapse of more than half of a century, during which period most remarkable discoveries in physical science have been made, this book is still timely and well worth reading—although I presume that it is

now out of print. Much could be written about this work but the insurmountable limitations of space in this magazine preclude the possibility of further comment thereon in these pages—a remark that is applicable to the other topics discussed in this sketch. In the year 1857, immediately after the publication of the work aforesaid, Dr. Simonton, a young man of twenty-six, removed to St. Paul, Minnesota—then, practically, a frontier town of what was known then as the "far-west"—where he resumed the practice of his profession in which he immediately took, and long held, high place, up to a couple of years prior to his decease, he having then retired upon an ample competence acquired through the practice of his profession. Shortly after his arrival, or about the year 1860, he was largely instrumental in organizing and promoting the Mercantile Library Association of St. Paul, the preliminary meeting for the organization whereof took place in his office. This was the first considerable circulating library in this region, and about twenty years afterward, when it had acquired a nucleus of about 8,000 volumes, it was purchased by the municipality and was merged into what is now the St. Paul Public Library which possesses nearly 100,000 volumes and in which, although not officially connected therewith, Dr. Simonton took deep interest as he was a constant and discriminating reader especially of scientific publications. About the same time he did like public service in promoting the St. Paul Muscial Society, he having been an accomplished violinist.

He was gifted with more than ordinary artistic skill and taste in the use of the brush and pencil, particularly in landscape, his productions in this line, while not numerous, and known chiefly to his family and friends,—he did not pose as an artist—possessing real merit, being true to nature and marked with a delicacy of treatment and artistic correctness in both drawing and coloring; but these amateur pursuits were only subsidiary to his chief delight—the mysteries and problems of astronomy, and the discussion thereof. A thorough knowledge of astronomical science in all its phases is vouchsafed to very few, as this study requires for its mastery not only time and patience but also high mathematical training and a peculiar mental aptitude; moreever it is popularly regarded as a study transcending ordinary comprehension and as leading to no practical, tangible results—a most erroneous and misleading impression which is very far from the truth, as is demonstrable; but at all times and in nearly every community no matter how crude, there is a certain

class, small perhaps in number, but intelligent enough to be interested in the phenomena of the heavens, and which is pleased to have its attention called thereto and to receive instruction thereon in a popular manner.

To this class especially, in the early days of St. Paul, Dr. Simonton ministered long and well, both by direct personal address and through his communications to the press and other publications, discussing current phenomena and those to occur, eclipses, occultations, comets, meteoric showers, etc., and explaining them lucidly in popular language. He was thoroughly versed in Descriptive Astronomy and the geography of the heavens and familiar with the host of noteworthy celestial objects, telescopic and other, taking great interest in the observations of double stars, variables, he having been endowed by nature with an extraordinary keenness of vision and power of discernment that would have served him well had he been a professional astronomer. Thoroughly devoted to, and attentive in, his professional duties, and a shrewd man of business, he was by no means a dreamer although he was an enthusiast in astronomical matters, and while his practice was extensive, he always found time to discuss such matters with his friends and acquaintances and all interested wherever they might be, either at their own homes, in his office, or at his residence, where he had, suitably mounted, a three and one-half inch refractor—for a time the only instrument of its kind in the city—and no matter how diffident, by reason of their unfamiliarity with the subject, or even how apathetic some of them may have been, he always succeeded in awakening their interest and implanting in their minds some positive knowledge, and a desire for further information on the subject, and even in the case of some of his hearers in imparting to them a measure of own interest and enthusiasm, he thus informally and almost insensibly to themselves, teaching many. In this respect Dr. Simonton possessed the essential qualities of a successful instructor and educator, although he made no pretense of being either, and I wish to advert particularly to this phase of his character and career, in grateful remembrance of the moral encouragement and practical assistance that, when I was becoming interested in astronomical science, he gave me, and which was freely extended throughout more than the third of a century, almost up to the time of his death, in a manner so unobtrusive that I have often been in doubt as to whether he fully realized its importance to the beneficiary; and there are others also

who have been similarly aided by him. About the year 1873 he assisted in founding the St. Paul Academy of Natural Sciences, a modest, but effective, institution that for the time and place was quite well-equipped for its work, it possessing a considerable collection, particularly in the mineralogical and paleontological lines, and which provided free lectures upon divers scientific subjects—prominent among which were astronomy and spectroscopy—one of the first of these having been delivered by Col. Ludlow of the Corps of Engineers, U. S. A., then Chief Engineer of the Dept. of Dakota, in 1874, upon the Transit of Venus about to take place on December 8th of that year. All these lectures were well attended for several years until the Academy succumbed under the stress of adverse financial conditions, much to the regret of Dr. Simonton who had taken great interest in it and whom I first met quite casually in its rooms, where he was perusing a volume of the American Ephemeris in which we were both interested, our mutual interest thus leading to an acquaintance and friendship that continued up to the time of his death, more than thirty-three years afterward, during which period his deep interest in astronomical matters and correlated subjects never abated to my certain knowledge—a fact that attests the firm hold which that science has upon its votaries, and one most fully exemplified in the case of Dr. Simonton.

Not content to let the astronomical section of the Academy be disrupted and its members dissociated by its failure, he gathered a few of us together in an informal coterie and invited us to meet occasionally at his office, which we did, papers on astronomical topics being read and discussed at these meetings, some of the papers having been of sufficient interest to attract attention, and to cause the publication of favorable comment thereon, abroad. These meetings were continued for about a year during which time Dr. Simonton was mentally casting about for ways and means of effecting and providing for a more permanent and larger organization, and seeking also suitable quarters therefor, and being a man of resource and tact he finally succeeded in this quest, through a concatenation of peculiarly favorable circumstances. In some manner he discovered that the constitution of the Minnesota Historical Society, a chartered and semi-official state institution having its rooms, library and collections in the capitol at St. Paul, was broad enough to permit the segregation of portions of its membership into "sections" for specific purposes of an intellectual

nature so that if some members desired to form an "astronomical section" they could do so, and that our little society could thus become affiliated with the Historical Society and partake of its privileges—not the least of which was the use of its council chamber in the state capitol, for our meetings. It so happened that at the head of that society was that venerable citizen of St. Paul, Hon. Alexander Ramsey, Ex-Governor of Minnesota, (both as a territory and as a state) Ex-United States Senator therefrom, and subsequently Secretary of War in the cabinet of President Hayes, and who had been a friend and neighbor of Dr. Simonton's father in Harrisburg, Pa., succeeding to the seat of that gentleman in Congress in 1843. Under these favorable circumstances Dr. Simonton succeeded in enlisting the interest and influence of Governor Ramsey in his project, and affiliation of our little organization with the Historical Society was effected about the year 1878, with that distinguished gentleman as the first President of the "Astronomical Section," a position that he held for nearly a year, or up to the time of his appointment as Secretary of War, in 1879, when he was succeeded in the presidency aforesaid by Professor William W. Payne of the chair of Mathematics and Astronomy in Carleton College at Northfield, Minnesota, who is now Director of Goodsell Observatory at that College. The original membership included also Dr. Simonton, Professor Thompson, then of the chair of Astronomy and Mathematics at the University of Minnesota; Major Allen and the late Col. Maguire, both of the Corps of Engineers of the United States Army—the latter at that time Chief Engineer of the Department of Dakota—and about half a dozen others including the writer. Frequent meetings were held and papers upon astronomical and correlated topics read and discussed, and individual opinions on mooted scientific questions exchanged in informal talks between the members—the whole proceedings being interesting, instructive and thoroughly enjoyed by all, particularly by Dr. Simonton himself, who was then in his element.

An amusing incident occurred at one of our evening meetings in the room in the old state capitol, upon which occasion it happened that one of the Justices of the Supreme Court of Minnesota found it necessary to hold a special session to hear arguments on a legal question, and as the courtroom in another part of the building was not at that time available, he made a request through the secretary of the Historical Society for the use of the room in which the Astronomical Section was

holding its meeting and was deeply immersed in *in medias res.* By a considerable majority the request was respectfully declined, an action that did not involve "contempt of court" but which indicated how seriously our little society regarded itself, and its consciousness of its dignity, rights and importance, and it may easily be guessed upon which side of the question Dr. Simonton cast his vote.

The course of the Astronomical Section ran smoothly and satisfactorily for several years until one evening in March 1881 while the legislature was in session, the capitol building was destroyed by fire, this catastrophe involving the loss of the room in which our society held so many interesting and profitable meetings; of its books, and a fragment of an iron meteorite that had fallen a short time before in northwestern Iowa and had been secured by the society through the efforts of Dr. Simonton and Professor Thompson.

A couple of months afterward the writer removed to Washington, D. C., and was thereafter uninformed of the career of the homeless society, but I think that its membership—never large—was depleted by the removal of some members to other fields, and that the remaining ones became discouraged by these adverse conditions, but Dr. Simonton's interest in the science did not abate as I knew through an occasional correspondence with him, mainly concerning current astronomical events, and from conversations with him during a visit which he made to Washington in 1883. In the year 1887, accompanied by his wife, he began an extended tour of Europe, his trip continuing about a year and a half during which he visited observatories and other intellectual centers on the continent and in the British Isles. At Nice, he held an extended interview with the distinguished astronomer Perrotin at his observatory there, and also met Flammarion in Paris. In England he attended the meetings of the British Association at Manchester, and at Edinburgh, Scotland, he came into contact with leading scientists and other distinguished persons of that country, and his subsequent narration to the writer—and others—of the details of the interviews with all the eminent men that he had the good fortune to meet during his tour was exceedingly interesting, as his conversational gifts were above the average. He dwelt with particular pleasure upon the circumstances of his visit in London to the venerable founder of the Young Men's Christian Association who received him in the room in which that great institution began its existence.

While, among the natural sciences, astronomy was his chief delight he placed spiritual considerations above all others, and was a deeply religious man, eminently just and righteous—but not self-righteous in the objectionable sense of that word—and his sincerity, honesty and simplicity were transparent and innate qualities. He was devoid and intolerant of cant, hypocrisy, deceit, sham and pretension of any kind, his characteristics in this respect, while both innate and resultants of his religious training, having also, I think, been fostered in a measure, by his study of the mathematical science of astronomy, the exactness whereof has a logical tendency to cultivate the these moral attributes.

Both through racial and family heritage, and also through personal predilection, his religious convictions were those of the Presbyterian form of the Christian faith, but while he was firm, and even uncompromising, in these, he was not intolerant of the honest convictions of others and never obtruded his own upon any one, the breadth of his mental scope and his intellectual acquirements precluding bigotry and prejudice, for he was a man of excellent mental poise, calm, judicious, analytical, and not prone to hasty reasoning or conclusions not absolutely warranted by facts, he, in this respect, following closely the injunction to prove all things and hold fast that which is true.

His demeanor was grave and dignified, but he was cordial and kindly in manner, and even genial—possessing a sense of humor that enabled him to appreciate a clean joke, witticism or anecdote, which he thoroughly enjoyed.

He joined the Central Presbyterian Church upon his settlement in St. Paul; was elected Superintendent of the Sabbath School in 1857, holding that position for several years, and was made an elder of the church in 1858 retaining that office up to the time of his death, nearly half a century later, and he was always devoted to, and foremost in, the works of his church during that long period of service. Although a man of affairs, he led "the simple life" in an ideal home, his immediate family consisting, of late years, of his wife and a son, James Carlisle Simonton, who is connected with the Traffic Department of the Northern Pacific Railway in St. Paul, in an important capacity, and who has inherited his father's noble traits of character, he being the youngest of five children four of whom—two sons and two daughters—passed away in childhood, their mother following them in 1875—whence it will be seen that the subject of this sketch was a man not unacquainted with grief,

in which he was, however, sustained by a characteristic Christian fortitude.

In 1879 he married an estimable lady of St. Paul—Mrs. Emma M. Campbell—who now survives, as do two of his brothers, Reverend William, and Professor James S. Simonton.

In person Dr. Simonton was of a little more than medium height, slender rather than robust, and of a somewhat nervous temperament, such as is frequently found in one of his fine mentality, and that, during the latter part of his life, superinduced a tendency to insomnia which was aggravated by any intense mental concentration, and interfered seriously with deep or prolonged application to study.

This he assigned as an adverse condition when I, knowing his devotion to astronomical science, and his natural aptitude therefore, several times suggested that he devote at least a portion of his time to systematic work and research therein. But his mode of living was always so simple and abstemious, that even when he was considerably past three score and ten his age was not specially in evidence; and he was active in both body and mind—even sprightly— up to a very short time prior to his death. Nor had his desire for the existence of a suitable astronomical society in St. Paul waned, and only a short time before he received the final summons, he, several times, earnestly discussed with me the possibility of reviving the old society, but as most of the members had either passed away, or dispersed, and a new generation had arisen which was devoted more to commericalism than to purely scientific pursuits, the times did not seem auspicious for the undertaking, which fact, together with some premonitions of failing health, forced him, very reluctantly indeed, to relinquish his cherished idea in this connection.

The labor necessary to overcome the inertia of a community, rather apathetic on this subject, seemed too great for him under the circumstances, but doubtless there was a considerable number of persons in this city who would have become members of such a society, as has been indicated by the recent formation of an "Astronomical Section" in the newly organized and comprehensive Institute of Arts and Sciences, in which, had his life and health been spared, Dr. Simonton would, without doubt, have taken a deep interest, and become an enthusiastic and valuable member.

About a year ago he paid me a friendly visit and on that occasion looked over some special work upon which I was then engaged, giving me advice concerning it and making suggestions

thereon that I have found to be sound and valuable, and his health and spirits seemed to be so fairly good, that I hoped that he, being then at leisure and possessing considerable mechanical ingenuity and dexterity in manipulation, would assist me in some particular, contemplated experiments in the electrical field. But this hope was not to be realized, for at that time the sun of life, for him, was low, and the shadows fast lengthening, and although neither of us had any premonition of the sad fact, our greetings on the occasion of that visit proved to be the final. *Ave atque Vale*!

Very shortly thereafter, for him, the twilight faded, the night fell and he sank to rest to wait the dawn of the Everlasting Day, and with his departure there went out from the walks of life a true, Christian, gentleman of the admirable old-school type, and a scholarly one; a good, useful, and substantial citizen, and a man without guile who was held in high esteem by all who had the honor and privilege of his friendship or, even more or less intimate, acquaintance.

It has appeared to me meet and just that a brief sketch of his life and work should find place in the pages of this magazine which, from to time, for the edification and encouragement of its readers, a majority of whom I presume are persons quite deeply interested in astronomy—true amateurs—thereof—has been pleased to record the intellectual attainments, scientific achievements and labors—modest though these may have been—and also the personal qualities and moral worth of earnest, enthusiastic workers in the field of astronomical science, who have passed beyond—and such an one, in very deed, was Thomas Davis Simonton.

St. Paul, Minnesota, August 1908.

DOOLITTLE'S MEASURES OF HOUGH DOUBLE STARS.*

G. W. HOUGH.

In 1901 Professor Eric Doolittle of the Flower Observatory began the re-measurement of the double stars discovered by myself with the 18-½ inch refractor of the Dearborn Observatory.

This work has been published by the University of Pennsylvania and contains 176 pages, quarto.

I am personally under great obligations to Professor Doolittle for undertaking so extensive a piece of work and I am pleased to say that it has been done in a more thorough manner than if undertaken by myself.

When the number of observations of each pair is taken into account, as well as the number of exceedingly close and difficult pairs which been examined and measured, I think it may rank as one of the most important monographs on double stars that has hitherto been published.

The telescope used had an object glass of 18-inch aperture by Brashear. The measurement of so many exceedingly difficult pairs indicates that its optical qualities are all that can be desired and it will rank with the best telescopes of that aperture now in use.

The author devotes nine pages to explanatory notes regarding the various catalogues, method of observing, and other necessary information.

In general, each pair has been measured on five different nights which adds greatly to the value of the work, especially in the case of exceedingly close or otherwise difficult pairs.

The catalogue contains 648 pairs, classified as follows.

Distance		No. pairs
0 K	0″.5	84
0.″5	— 1″	74
1″	— 2″	101
2″	— 5″	172
Over 5″		218

It appears from the above table that more than 25 per cent are less than 1″ in distance and more than 13 per cent less than 0″.5.

During the last thirty years, a comparatively large number of pairs under 0″.5 in distance has been discovered by Burnham, See, Hussey, Aitken and myself.

* Read before Astronomical and Astrophysical Society, Put-in-Bay, Ohio, August, 1908.

Many of these excessively close pairs, especially some of those found at the Lick Observatory, will undoubtedly prove to be very short period binaries.

The author concluded from his measures that thirty pairs in the above catalogue are clearly binary system, after excluding all pairs which cannot now be seen double or are presumed to be single.

He also finds forty-nine pairs which have considerable proper motion. He has classified fifteen pairs as single, nearly all of which have also been examined at the Lick Observatory. I presume a large proportion of the pairs in this class are in reality single. I notice, however, one of these pairs has been observed at Greenwich, since the publication of his measures.

If a star is presumably single there is no use in wasting valuable time, but if, on the contrary, there is a reasonable probability that it was double at the time of discovery, it is likely to turn out a short period binary and should be examined occasionally.

It sometimes happens that a pair is easily seen at the time of discovery, either because there was good seeing at the time or that the components were at the maximum distance. Hence, the discovery position, if simply an estimate, should have great weight in deciding on its probable duplicity.

The rapid binary, 13 Ceti, is a good example. At the date of discovery in 1886, it was near its maximum distance and was readily seen, while four years later it was single with the 36-inch Lick telescope. In the discovery of a pair of equal magnitude, if the distance of the components at the time of discovery is not much greater than the theoretical separating power of the telescope, there is a chance of mistaking a spurious elongation as real. But when the distance is a measurable quantity and the star is examined with different eye pieces on different nights, there is a very slight chance for error.

In the case of very unequal pairs, the visibility of the small star will depend on its distance from the primary. Just what this minimum distance is for a given pair and telescope, is not definitely known. From what we know regarding unequal pairs, which have been catalogued, I think it is probable that many of the bright stars are accompanied by small companions that are entirely beyond the reach of our present optical powers.

The companion to Sirius is a good example of our inability

to see a small star when at a certain distance from the primary.

The stars which I have found double during occultation by the Moon were, at the time of discovery, I think too difficult to be seen with any telescope in use, but it is possible that in time the components may be at such a distance apart as to be visible.

The most interesting stars of this class are

τ	Tauri	1899	.80 n.p.	0″.15 to 0″.4	4.4—9
ξ	Ophiuchi	1907	.70 foll	1″ tol″.5	4.4—11

In the second case, the small companion was visible at the dark limb of the Moon for about four seconds after the disappearance of the primary.

If occultations of the naked eye stars were more generally observed with a large aperture, I think we should find a considerable number similar to the above class of doubles.

Doolittle also computed an orbit of H_{α} 212 = 13 Ceti and found elements agreeing very closely with the orbit previously determined by Aitken. The periods for the two computations are 7.42 and 7.35 years respectively.

According to this period, 13 Ceti is the second most rapid binary now known.

We are under great obligations to Professor Aitken for securing a definitive orbit in so short a time, for without his consecutive series of measures, it might have required many years for this purpose, as has been the case with other rapid binaries.

I may add also in this connection that the Greenwich Observatory has undertaken the observation of about 500 pairs, found in the above catalogue and has already published measures for a considerable number.

The material which has been secured during the first 30 years and brought together by Prof. Burnham in his general catalogue will enable the next generation of astronomers to have a wider field of research on double stars than has been possible in the past.

Evanston, Ill.

THE POPE AND THE COMET.

WILLIAM F. RIGGE.

For Popular Astronomy.

It seems that no article can be written on Halley's comet without bringing in the oft-told story of the bull which Pope Callixtus III so ineffectually launched against it, or of the Angelus bells which were rung to frighten it away, or of the prayers which were to deliver the Christian world from the devil, the Turk and the comet. The truth-loving reader will, therefore, be probably most intensely surprised when he hears that, as an actual fact of sober history, there is no truth whatever in the story, not even in its least details. And the proof is easy and solid.

First. While Newcomb calls the bull a myth, but along with the Columbian and Chambers Encyclopedias believes that prayers were ordered to be said against the comet, no allusion whatever to the pope, the bells and the prayers is made by Sir John Herschell, Grant, Young, Comstock, Todd, Langley, the American Cyclopedia, the Encyclopedia Americana, the Encyclopedia Britannica of 1902, etc. While this may be a negative argument, it is not, however, an inconclusive one, for why should these eminent authorities, all of them non-catholic, not mention the story if it is true, when so many other writers speak of it?

Second. The Bullarium Romanum is a large series of volumes containing in the original Latin all the official documents ever issued by the popes, from St. Peter down to our own day. Owing to the definiteness of the reference and the short reign of Callixtus III, it was an easy task for me to read all the documents of this pope, and I can attest from my own personal knowledge that not only is there no bull against or concerning a comet, there is not even a paragraph, nor a phrase, nor a word, which might be construed to refer to a comet.

Third. The story is so universally told and is to be found in so many writers, such as Arago, Draper, Babinet, Guillemin, White of Cornell, etc., that most persons are really excusable*

* Note. I lately had the privilege of visiting one of the first astronomers of the country in his own observatory. Seeing some photographs of comets, I remarked pleasantly that is was about time the pope got his bull ready if he

when they are misled into the conviction of its truth, and then simply copy it and pass it on to the next generation. If the reader of these lines is really interested in the matter, I would refer him to an able article entitled "Of a Bull and a Comet" written by John Gerard, S. J., and published in "The Month", London, in February 1907. Here the whole story is traced to its fountain head, and it is shown by the best authorities, nearly all of them non-catholic, that not only no bull was ever launched against the comet, but prayers were not even ordered to be said against it, although the prevailing opinion of the scientific men of the time was that the comet foreboded calamity to the earth. Any one that wishes it may obtain a free reprint of the article in question by applying to the Superintendent of Parish Schools, Broad and Vine Streets, Philadelphia.

Fourth. The article just referred to traces the origin of the whole story about the bull against the comet to this one paragraph of Platina, in his Vitae Pontificum, published in Venice in 1479. As this writer was not only in Rome at the time, but was also archivist of the Vatican when he wrote his history, his authority ought to be of the utmost value. These are his exact words:

"A hairy and fiery comet having then made its appearance for several days, as the mathematicians declared that there would follow a grievous pestilence, dearth, and some great calamity, Callixtus—to avert the wrath of God—ordered supplications, that if evils were impending for the human race, He would turn all upon the Turks, the enemies of the Christian name. He likewise ordered, to move God by continual entreaty, that notice should be given by the bells to all the faithful, at midday, to aid by their prayers those engaged in battle with the Turk."

Let us read the words again and study them carefully. 1. The pope did not issue a bull against the comet, he ordered supplications. 2. He ordered these conditionally, "that if evils were impending," prudently neither admitting nor reject-

wished to prevent the return of Halley's comet. "Do you know", he said, "I was foolish enough to give credence to this story lately in a public lecture? I was at once deservedly, yet politely, taken to task for it, and I shall certainly never be guilty of such ignorance again." When I told him I intended to write up this story in Popular Astronomy, he urged me: "Do so, by all means, because it is repeated so often and in so many magazines, that people really believe it to be true."

ing the authority of the mathematicians who declared that pestilence, dearth and some great calamity would follow the appearance of the comet. 3. He assumes no authority over the comet nor bids it be gone, he orders supplications, declaring himself to be a suppliant, that if evils were impending, God would turn them upon the enemies of the Christian name. 4. Bells are to be rung to remind the faithful to pray, not to frighten away the comet.

This one quotation from one author, which has been the germ of the whole comet story, weakened as it is by our simple analysis, becomes of no value whatever when we apply the rules of ordinary historical cricitism. We have only the word of Platina that the pope ordered supplications to be made and bells to be rung, he neither refers to any papal document, nor does he quote the pope's exact words. Now, as the Bullarium Romanum contains all the official documents of all the popes, and as not one of the declarations of Callixtus III alludes in any manner whatever, directly or indirectly, to a comet, we have every reason to dismiss the testimony of Platina altogether. For this same reason we must also reject the testimony of each and every writer that mentions the comet story or any of its details, because not a single one of them has ever given the slightest reference to any official document ever promulgated by Callixtus III whether in the Bullarium Romanum or out of it, nor supported his assertion by anything stronger than a quotation from a previous writer who was equally deficient in his historical proofs.

There is, therefore, no foundation whatever for the story that Callixtus III issued a bull against or concerning a comet, that he ordered bells to be rung to frighten it away, and that he ordered prayers to be said to deliver the world from its influence.

Creighton University, Observatory,
Omaha, Nebraska.

SOME RECENT STUDIES OF THE SOLAR SURFACE.

ROSE O'HALLORAN.

For Popular Astronomy.

The relative distribution of spots on the Sun's surface within a definite period, their general aspects, and their number are details of solar study easily obtained and well worthy of record. There is a hidden cause for each one of them. It has long been known that the southern hemisphere of the Sun is, on the whole, more spotted than the northern. According to Comstock's text-book of Astronomy, disturbance north of the solar equator was less than half that in the southern zones from 1879 to 1890, and an enumeration of the separate areas of discoloration that I observed from November 1891 to November 1901 showed that the disparity continued during the succeeding cycle, though on a decreased scale, the difference being in about the proportion of 3 to 4. In 1902-3 it may be fairly represented by the numbers 7 and 8; but in 1904 a gradual transference took place, the greatest activity becoming slightly predominant in the northern hemisphere. This continued until July 1906, when a pretty even distribution set in lasting until March, 1907, and then the southern hemisphere again became the scene of greater activity. The following record dating from November 1906 to December 1907, a period of fourteen months, includes this last hemispheric transference.

Record of Sun-Spots.

Year	Month	No. of spots	Solar Hemisphere North	Solar Hemisphere South	Unknown	No. of Days of Observation
1906	Nov.	12	4	6	2	26
	Dec.	17	8	6	3	22
1907	Jan.	14	4	8	2	17
	Feb.	18	7	3	8	18
	March	11	5	4	2	20
	April	11	2	6	3	25
	May	9	2	3	4	26
	June	4	1	2	1	26
	July	10	4	6		19
	Aug.	12	3	8	1	23
	Sept.	14	5	5	4	25
	Oct.	9	3	4	2	25
	Nov.	12	5	5	2	24
	Dec.	13	4	7	2	20
		166	57	73	36	317

I have applied the word "spot" to any discoloration whether single or in sections closely adjacent, provided the whole be isolated about twenty degrees, as it is then probably due to one immediate cause.

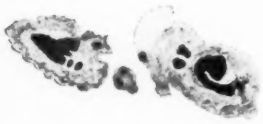
Such numerical estimates have a supplementary value as the accuracy of a real measurement is diminished by the fact that sun-spots exhibit much irregularity of outline and are also more or less affected by foreshortening.

With regard to the shape of spots, tendencies towards the simple geometrical forms are occasionally noticeable; and in a visual teleseope examination of umbræ that appeared during these fourteen months, the outlines of seventy were noted when crossing the disk centrally. Of this number one had an approach to squareness, five to roundness, ten to ovality, eleven to triangularity, while the remaining forty-four admitted of no classification. The triangular form, sometimes called pear-shaped, has long been recognized as a frequent deviation from the usual grotesque irregularity. Of the 166 observed 26 may be classed as of mean size and 13 as large. Conspicuity is as important as extent of area, for a spot only 50,000 miles in diameter with an immense umbra may challenge the unaided vision while a scattered or penumbral group of 70,000 miles passes unnoticed.

The visibility of two eruptions, one in the end of January and the other in the beginning of February, 1907, depended more on their round, black umbræ than on their scant penumbral fragments. Much alike in aspect, only in very clear intervals were either discernible without magnifying power as they transited centrally, one north and the other south, eight days afterwards, in southerly zones. When the latter was on the west side of the disk, another group far in the rear enlarged and surpassed it in size and conspicuity. Thirty-seven umbræ, two of which were more than medium size created the discoloring effect of this reinforcement which formed another distinct blur on the southern tracts from the eleventh to the fourteenth of the month. Telescopically, it was in view for thirteen days, a vast length of 130,000 miles prolonging its transit to the eighteenth, when seemingly on the west limb of the Sun.

These solar storms seem to have outlasted one rotation, and in reduced size and changed form to have transited again in due time. The special feature of an equally large

group that appeared south of the equator in the June following, was an indication of cyclonic motion. Tendency to a circling formation in its umbræ and fragments was evident with many changes from the sixteenth to the twenty-second of that month when foreshortening obscured its outlines. One of its remarkable phases is well shown in the accompanying illustration.



SUN-SPOT, JUNE 16, 1907
8:40 A. M.

Very interesting in another respect was the triangular group of November. When centered on the fifteenth of the month, a brilliant prominence was seen to flare from the Sun's surface to the marvellous height of 325,000 miles. The observer, Dr.

SUN-SPOT, NOVEMBER 14, 1907. 8:40 A. M.

Amban of Radcliffe Observatory, England, ascertained that it had moved with the velocity of 10,000 miles in one minute, and having remained in view for half an hour, it gradually broke in

fragments and disappeared. Such violent activity is known to occur in the neighborhood of large eruptions, and the changed aspect of the spot, as shown by a comparison of the drawings

Sun-Spot, November, 17, 1907. 8:40 A. M.

of the fourteenth and seventeenth may be connected with the uprush of the remarkable Sun flame.

The later sketch is on an enlarged scale, but the changes are quite recognizable, especially the scattered effect when, owing to foreshortening, a more compact appearance was to be expected. This much disturbed area was north of the solar equator. With the exception of an oscillation southward in April, spottedness predominated in the northern zones both in size and number during the present year (1908) up to the end of May. Only spots of medium dimensions appeared during these months, the largest member of the group being that which measured 32,000 miles in diameter on the thirty-first of May.

On four days of this year, namely February the eighteenth, March the third, and the twenty-sixth, and May the twenty-fifth, the disk was unspotted in a four inch lens; and though the maximum is not yet passed, the minimum due in 1912 will probably indicate its approach before long.

San Francisco, California,
June 1908.

PRELIMINARY NOTE ON THE OBSERVATION OF SEVERAL HARVARD VARIABLE STARS DISCOVERED IN 1907.

WM. E. SPERRA.

For Popular Astronomy.

Through the kindness of Prof. E. C. Pickering of Harvard College Observatory, who furnished charts for the identification of fifteen of the variable stars announced in the H. C. O. Circulars, Nos. 127, 132, and 133, as follows: 42, 43, 45, 46, 63, 64, 147, 148, 154, 158, 160, 161, 162, 174, and 175.1907. 63 and 64.1907 had already been assigned the definite notation of ST and TT Aquilae. Of all the remaining thirteen stars, variation has been detected in 42, 43, 45, 147, 148, 158, 174 and 175: no trace of variation has been noted in 46, 160 and 162. But as this paper is intended to deal with the second and third of the above list only, further details as to the variation of the others will be deferred for a future paper.

43 and 45. 1907 are both in the constellation Draconis and in adjacent fields. Observations of both were commenced on the night of 1908 May 24. For the first three weeks one observation was obtained a night. The first and second night's observation of 43 showed it to be undoubtedly a short period, variable, as on May 24 it was near minimum, whereas on May 25 it was near maximum, but the series being broken by cloudy weather, the true nature of its variation was not suspected until the night of June 17, when a rise was obtained which showed its period to be not a matter of days as was supposed from the first observations, but of hours only. A change in the plan of observation was necessary, and an all night series yielded a minimum for June 20.501 L. M. T., a maximum was observed on June 21.427, 23.431, and 25.398, a minimum on June 26.415, and an all night series on June 27 a decline from maximum. Thus it appeared that similar phases occurred on alternate nights, but at an earlier hour. From a discussion of these observations a period of a little less than 16 hours was deduced—0.6595 days.

An ephemeris was prepared with 1908 May 24.0819 as epoch, and most of the maxima were fairly well represented, the minima not so well. A single observation on the morning of July 4.628 at maximum light served as a check for the

ephemeris date of July 4.6204. But it was found that a slightly longer period (0.660) days was required for the minima. Now the basis of the second period was the observed minima of June 20 to June 30, while the maxima went back to May 27.385 to June 26.380, a significant fact as will appear later. These results were communicated by letter to Harvard College Observatory, on July 5.

While the star was kept constantly under observation no comparison was made with my computed ephemeris until August 24, when it was found at minimum, while the ephemeris called for a maximum. This was intolerable and a new discussion was made which included 175 observations extending to Sept. 9. In the first discussion no account was taken of the effect of the equation of light, but in this latter the necessary corrections were made. It was soon found no constant period would represent all the observations within a two or three hours residual, and the evidence was for an unmistakable increase in the length of the period. May 26 to June 21, an interval of 38 periods, its mean length was 0.65909 days; June 21 to July 28 an interval of 56 periods gave as the mean length 0.660409 days; July 28 to Sept. 5 an interval of 59 periods resulted in a mean length of 0.66089 days. Now it is readily seen why it is necessary to use a longer period to represent the minima of June 20 to June 30, as referred to above.

Now as the period is a little less than 16 hours, the maxima fall earlier on each succeeding alternate day, thus resulting in a precession of the maxima, which in about a month's time cause the succeeding maximum to be observable at the same hour of the day. Now if the period of variation is constant, the period of precession will also be constant, and *vice versa*. The first precession period May 27.385 to June 27.380 is an interval of 31 days; the next June 27 to Aug. 1, an interval of 35 days; Aug. 1 to Sept, 7, an interval of 37 days. Showing an increase in length of the precession period, a necessary sequence to the increase in length of period.

The rise requires about six hours, and for the first four is very slow, the decline is very slow requiring about ten hours with a halt six hours after maximum. I have not worked the magnitude range out yet, but is about that given in the H. C. O. Circular No. 127. In a forthcoming paper, I hope to

give a detailed result of the observations, and have already exceeded in the intent of this paper.

45. 1907 Draconis

This was a much more difficult star to deal with, as in May and June for two succeeding nights it would be bright and the next two faint. And with the weather breaking in, it was June 20 before its short period was suspected, and it was nearly a month later before it was evident that the phases were repeating every fourth day. From a discussion of 122 observations 1908 May 24 to Aug. 20 a mean of 3.9866 days was found for this cycle. But it was still uncertain how many periods were represented by the four days, as my observations covered only about six hours out of each twenty-four. But it was evident that the number must be odd, as the time, four days, was even. I had succeeded in observing only one maximum out of each four days. By successive trials it was found to be divided in seven periods; one period being 0.56952 days, or a little over $13^h\ 40^m$. A mean light curve was constructed, and all observations were fairly well represented.

The rise requires about four hours, at first slow after minimum for an hour and a half, then very rapid until maximum, no halt is made and the decline sets in immediately, and for over an hour after is as rapid as the rise, a halt is made at two to three hours after maximum, the decline then increases for nearly two hours or more, and then for the next five hours is very flat--the lowest point being reached ten hours after maximum. The range is about a magnitude, or 19 light steps on my scale. My elements for this star are, 1908 May 24.0963—0.56952E.

On the night of Aug. 29.490 maximum No. 3 in the series of seven was observed for the first time, giving a residual $O - C = +.0053$ or less than 8^m minus the equation of time—about three minutes. It will yet remain to be seen how closely future maxima will follow the elements which depend on 160 periods. As in the case of the star 43.1907 this is only preliminary.

Cleveland, Ohio,
September 15, 1908.

THE ORBIT OF THE EIGHTH SATELLITE OF JUPITER.

R. T. CRAWFORD.
W. F. MEYER.

The following observations have been used in the determination of the orbit of the eighth satellite of Jupiter:

Gr. M. T. 1908	α (1908.0)	δ (1908.0)	
Jan. 27.5288	131° 27′ 50″	+18° 05′ 05″	Greenwich
March 8.8486	127 09 48	+19 31 36	Lick
April 29.7023	128 26 03	+19 35 49	Lick

The method employed is Leuschner's "Analytical Method of Determining the Orbits of New Satellites," which was used here with success in determining the orbit of the seventh satellite. This method has not been published, but an outline of it was given before the 1906 meeting of the Astronomical and Astrophysical Society of America. An abstract of it and of the results of its application to the case of the seventh satellite were printed in *Science*, n. s. 23: 441-460, and referred to in *Nature*, 74: 64, and in *Publications of the Astronomical Society of the Pacific*, 18, 135. It will soon appear in full as a part of Vol. VII of the *Publications of the Lick Observatory*.

The computation has been based upon the supposition that Jupiter is the primary and the Sun is the principal disturbing body. The determination then gives the osculating orbit for the middle date (March 8), in which the attraction of the Sun as a disturbing body during the period covered by the observations (January 27-April 29) is fully taken into account.

The computation leads to two solutions. For the first the logarithm of the distance from Jupiter at the time of the middle date is $\log r = 9.23826$; for the second $\log r = 9.11627$. The second solution gives an hyperbolic orbit with $\log e = 1.13199$. The elements from the first solution are:

Epoch and Osculation 1908 March 8.8233 Gr. M. T.

$$\left.\begin{aligned} M_0 &= 287°.226 \\ \omega &= 61.670 \\ \Omega &= 235.924 \\ i &= 144.854 \end{aligned}\right\} \text{Equator 1908.0}$$

$$\begin{aligned} \phi &= 28.824 \\ \mu &= 0.47702 \\ P &= 2.0662 \text{ yrs.} \end{aligned}$$

In this method there would result ordinarily two sets of elliptic elements, one with motion direct, the other retrograde. In such an event, as in the case of the seventh satellite, it is

necessary to carry on both solutions to see which gives the better representation of observations other than those used in the computation, before decision can be made as to which is the real orbit. In this case, however, one solution, *viz.*, the hyperbola, means nothing under the supposition that the object is a satellite; so the computation was continued for the ellipse only.

The special perturbations due to the action of the Sun were computed by Encke's method as adapted to this problem by Leuschner. Applying these to the rectangular coördinates determined from the osculating elements and computing the places for the dates of five observations the following representation results:

O—C	Jan. 27	Feb. 22	Mar. 8	April 1	April 29
$\Delta\alpha$	−43″	−10″	0″	+38″	+2′ 27″
$\Delta\delta$	+ 7	+ 4	0	−14	−0 51

The ordinary methods of correcting elements to remove residuals failed in this case. Resort was had to the method of arbitrary variation of elements. The fourth approximation leads to the following representation for the same five dates:

O—C	I	II	III	IV	V
$\Delta\alpha \cos\delta$	+4″	+12″	+1″	−9″	+5″
$\Delta\delta$	0	− 3	−1	+3	+1

The first, third and fifth of these are the residuals for the observations upon which the orbit is based. They are well within the errors of observation and outstanding perturbations, so the representation is considered satisfactory and the computation was stopped at this point. The two intermediate places are so well represented that there can be no doubt of the correctness of the supposition that the object is moving about Jupiter as primary.

The maximum effect of the attraction of the Sun is 10″ in right ascension and 5″ in declination. These are for April 29.

The last approximation for the removal of the residuals gives the following:

ELEMENTS.

Epoch and Osculation 1908 March 8.8233 Gr. M. T.

$$\begin{aligned} M_0 &= 294^\circ.286 \\ \omega &= 51.143 \\ \Omega &= 236.204 \quad \text{Equator 1908.0} \\ i &= 145.795 \\ \phi &= 26.073 \\ \mu &= 0.38680 \\ \log a &= 9.26412 \\ P &= 2.5482 \text{ (yrs.)} \end{aligned}$$

CONSTANTS FOR THE EQUATOR 1908.0.

$x = r\ [9.94653]\ \sin\ (270°.128 + v)$
$y = r\ [9.97766]\ \sin\ (\ 350.110 + v)$
$z = r\ [9.74986]\ \sin\ (\ \ 51.143 + v)$

An ephemeris is based upon these elements and the special perturbations due to the attraction of the Sun will soon be forthcoming.

A part of the check computation was performed by Mr. A. J. Champreux.

Lick Observatory Bulletin No. 137.
August 21, 1908.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

FOR POPULAR ASTRONOMY.

Part III. (Continued.)

THE NATURE OF THE SOLAR RADIATIONS AND THEIR RELATION TO TERRESTRIAL MAGNETISM AND OTHER METEOROLOGICAL PHENOMENA.

The hypothesis that the impacts of the ultimate particles of the atmospheric gases are the cause of the pressure of the atmosphere was enunciated first by Daniel Bernouilli in his work *Hydrodynamica*, published in 1738, (his view being shown to be correct by the English physicist Joule in 1848, this theory being subsequently elucidated by Clausius Maxwell and others) and mine, while apparently trivial has, as stated, led to important practical results unachieved by said kinetic theory.

Pressure (P) being thus proportional to the number (N) of revolutions, or vibrations, of the atoms, in unit-time, which number under my theory, as aforesaid, is proportional to the absolute temperature (T), to the fundamental linear orbital velocity (V_0) and to the mass (M) in unit-volume the following are algebraic expressions therefor; $P = MNV_0 = MTV_0$; (a). For any variable volume (V') we have $D = \frac{M}{V'}$,

and the aforesaid equations, when the fundamental orbital velocity (V_0) is taken as unity—as in the case of any definite gas, such as atmospheric air, are reducible to the following; $P = DN$ and $P = DT$; (β), the second of which expresses the well established fact of the thermodynamics of gases, "that the pressure of any gas is proportional to its density multiplied by its absolute temperature, and that when the latter is constant, the pressure is proportional simply to the density (which is Boyle's law), the first expression in the case of variable temperature being that for the law of Charles or of Gay Lassae, and through these expressions the relation between my theory and the ordinary kinetic theory of gases becomes apparent.

The structure of a single spherical molecule constituted of revolving atoms moving according to the postulates of my theory in this respect, involves all the principles of Hydromechanics, the molecule being a "center of force" or a reservoir of kinetic energy, exerted equally in all directions, a condition that fully explains the well-known fact that fluid pressures are exerted equally in all directions when the fluids are confined in a vessel. In the interior of a gaseous mass composed of such molecules so confined, the pressure exerted by any one molecule is under normal conditions exactly counterbalanced by the pressure of similar surroundings and contiguous molecules, the internal mass being therefore in equilibrum to pressure, but in the single layer, or as it may be called interface, in immediate contact with the interior surface of the walls of the vessel, there is an unbalanced pressure caused by the impacts of the atoms of one-half of the layer of molecules in contact with unit-surface, in unit-time, the other half being directed against, and balanced by, the impacts of the atoms of the contiguous internal molecules, an equal pressure caused by one-half of the impulsive forces of a single layer of molecules being exerted likewise, but in an opposite direction against unit-surface of the opposite wall of the vessel.

We may regard this force of pressure in one direction as "positive," and that in the opposite direction as "negative," the arithmetical sum being equal to the total pressure of all the molecules in a layer, and the algebraic resultant being o, which expresses the condition of equilibrium among all the molecules within this superficial layer, the internal molecules acting simply as media for the transmission of pressures and the propagation of radiant energy.

The concept of polarity is therefore again introduced and it

will be demonstrated presently that all the phenomena of electricity and magnetism are traceable to the mass and motions of the atoms in this single layer of molecules only, it being the seat of electro-motive force and also of that similar and correlated form of potential or pressure which we call the temperature of a radiating surface, and which is the mainspring keeping in motion those undulatory vibrations which give rise to the phenomena of radiant heat and light; the kinematics of this "interface" will now be discussed.

From Analytical Mechanics we know that the kinetic energy (E_a) of a single atom (as of any material body) of mass (m) moving with a linear velocity (V_o) per second is expressed by the equation $E_a = \frac{1}{2}mV_o^2$; (γ) and that the like energy(E_m) of a molecule composed of any number (n) of these atoms is determinable through the equation $E_m = \frac{1}{2}n\,m\,V_o^2$; ($\delta$) the kinetic energy ($E_s$) of a single layer containing any number (s) of these molecules, being equal to sEm.

The molecules being spherical it is evident that the number (s) in contact with unit-surface is equal to $\frac{1}{d^2}$, the denominator being the square of the diameter (d) of the molecule, and if this diameter be expressed in English inches the unit-surface is one square inch while if it be in centimeters this area is the square centimeter so that $E_s = \frac{n\,m\,V_o^2}{2\,d^2}$; ($\epsilon$)

In this equation V_o represents the fundamental linear orbital velocity of the atoms of the molecules of the atmospheric gases under the normal conditions of absolute temperature (T_o) and pressure (P_a) these being $T_o = 491.66$ degrees Fahrenheit and $P_a = 14.730$ pounds per square inch, and it is equal to T_oV_1, when V_1 represents the fundamental linear, orbital velocity corresponding to absolute temperature $T_1 = 1°$, the temperatures designated by T in general being proportional to the number (N) of revolutions, or to the angular velocity of the atoms in their orbits. The fundamental linear orbital velocity (V_1) is that of the atoms of the molecule of the ether and is equal to $2\pi V_1$ or to 2π times the "velocity of light" (V_l) and furthermore since the mass (M) of a molecule is equal to the product of the mass (m) of an atom and the number (n) of atoms in the molecule $M = nm$, and substituting M and also the aforesaid equivalent expressions for V_1 in equation (ϵ) we have the following group of equivalent algebraic expressions for the kinetic energy (E_s) of

the single layer of molecules, or "interface," aforesaid, due to the mass and velocity of the atoms thereof.

$$E_o = \frac{n\,m}{2\,d^2} \cdot V_o^2 = \frac{M}{2d^2} \cdot T_o^2 V_1^2 = \frac{2\pi M}{d^2} \cdot T_o^2 V_1^2 \quad (\mu)$$

all of which are in foot-pounds if English units are used and in dynecentimeters per second, or ergs, if units of the C G S system are employed. Morever, the normal absolute temperature (T_o) of the atmospheric gases is equal to $D^{\frac{1}{6}}$ when D represents the volume density of the luminiferous ether relative to the similar normal atmospheric density which is taken as 1, and therefore, $T_o^2 = D^{\frac{1}{3}}$, this representing the square of the linear orbital velocity (V_o) of the atoms of the atmospheric gases, relative to the corresponding velocity (V_1) of the atoms of the ether, the relative velocity itself being expressed by $D^{\frac{1}{6}}$ Substituting this equivalent of T_o in the two right-hand expressions of equation (η) there results the following:

$$E_s = \frac{M}{d2^2} \cdot V_1^2 D^{\frac{1}{3}} = \frac{2\pi^2 M}{d_2} \cdot V_1^2 D^{\frac{1}{3}} \quad (\zeta)$$

A division of the first of the expressions on the right hand side of the equation (η) by the velocity (V_1),and the third by its equivalent, $2\pi V_1$, gives the following expressions for the normal pressure (P_a) of the atmosphere.

$$Pa = \frac{n\,m}{2\,d^2} \frac{V_o^2}{V_1} = \frac{M}{2d^2} T_o^2 V_1 = \frac{\pi M T^2}{d^2} T^2{}_o V_1 = \frac{M}{2d^2} V_1 D^{\frac{1}{3}} = \frac{\pi M}{d^2} V_1 D^{\frac{1}{3}} ; \quad (\theta)$$

and since "weight" (W) is equal to "mass" (M) multiplied by the terrestrial force of gravity (g), we may substitute $\frac{W}{g}$ for M in all the above equations, the resulting expressions for P_a being the following:

$$Pa = \frac{W}{2g\,d^2} T_o V_o = \frac{W}{2g\,d^2} \quad T_o^2 V_1 = \frac{\pi W}{g\,d^2} T_o^2 V_1 = \frac{W}{2g\,d^2} V_1 D^{\frac{1}{3}} = \frac{\pi W}{g\,d^2} = V^2 D^{\frac{1}{3}} ; \quad (\lambda)$$

All of the equations above set forth for the kinetic energy of an atom and of a molecule composed of an enormous—but definite—number of these atoms, and of a single layer of unit-area of these molecules, as well as the algebraic expressions for gaseous pressure, are fully satisfied to within considerably less than one-tenth of one per cent, or to one part in less than a thousand by the absolute numerical values of the many literal factors that appear in the right hand members of these al-

gebraic expressions. These numerical values I have determined through a rigorous analysis based upon the principles of my theory and which are tabulated on a following page, the value of the normal atmospheric pressure (P_a), which involves all these values and which I have determined theoretically through equation(θ) and (γ) being 14.730 pounds, avoirdupois, per square inch, which value is identical—to the third place of decimals—with that resulting from numerous observations, or measurements, of this pressure, made by several well-known physicists of the highest repute, at different times in the recent past. A similiar, and fully satisfactory, agreement exists in the case of the electro-magnetic, electrostatic and electro-chemical units and also in that of the strength of the terrestrial magnetic poles all of which I have derived in absolute measurements of the C G S system, through rigorous analytical expressions based upon the principles of my theory, the normal atmospheric pressure(P_a) in grams per square centimeter being the basic quantity upon which all these electrical and magnetic units rest.

The algebraic expressions for the law of radiation, in the case of both heat and light, which I have derived in like manner give equally satisfactory results, my theoretically determined values agreeing well with those of observation and experiment, as will be demonstrated, and with all these data at hand, the specific nature of the solar radiations and their properties, qualitative and quantitative, can be definitely determined.

According to my theory all electrical action is primarily the result of the disruption of the whole, or a part, of a molecule of gaseous matter, the dissociation of each pair of conjugate atoms thereof which form the atomic couples, and the subsequent recombination of these atoms into a normal molecule, "dissociation" being regarded as positive, and "recombination" as negative, action which, in the ultimate analysis, is reducible, simply, to the motions of the masses of the atoms of said molecule, and results in the causation of the thermal, luminous, and mechanical effects that observation has shown to be concomitant, and correlated phenomena of electrical action which is thus primarily a purely mechanical process.

A molecule of a gas, consisting, as it does under my theory, of myriads of solid, and superlatively dense, atoms revolving with enormous velocity around the center of the molecule, is in effect, a solid shell enclosing the only absolute void, or vacuum, in the material universe, as is evidenced by the fact that,

no matter how far the exhaustion of a gas, such as atmospheric air—from a bulb or tube, be carried (even could it be to the practically unattainable, low density and pressure of the ether in space) there is always a remnant of gaseous matter within the vessel, the molecules of this residual matter expanding as the pressure due to the molecules of the portion of the gas exhausted, or removed, from the vessel, is decreased—there remaining therefore a finite density and corresponding pressure although these may be very low, as the $\frac{1}{1{,}000{,}000}$ of an atmosphere attained in the bulb of an incandescent electric lamp, or the $\frac{1}{5{,}000{,}000}$ or less attained in the vacuum tubes, such as those of Crookes.

The following tables, in the first part of which the numerical quantities are expressed in English units and in the second in the units of the C G S system (the unit of time in both being the second) contain the values in absolute measurement of all the literal quantities which are factors in the algebraic equations derived from the principles of my theory and set forth on preceding pages.

In each table they are given, first for atmospheric air at the standard normal density, pressure and temperature, the density being taken as 1, the pressure (P_a) at 14.730 pounds avoirdupois per square inch, and the absolute temperature (T_a) at 401.66 degrees, or 32 degrees Fahrenheit, while in the second table the normal pressure is 1035.2 grams per square centimeter; and secondly for the luminiferous ether, the values in this case being set forth in the lower part of each table, the density (D) of the ether, relative to that of air at 32° Fahrenheit, being $\frac{1}{1412 \times 10^{13}}$, while for air at nearly 100° below the Fahrenheit zero, or at 360° absolute, which is the intrinsic temperature of air, free from all the heating effects of the Sun, this relative density of the ether is $\frac{1}{1926 \times 10^{13}}$ which is the value set forth in the part of the paper published in the February number of POPULAR ASTRONOMY. In the first column of numbers, common to both tables, are set forth the numerical values of the diameter (d) of a normal molecule, in inches and centimeters, respectively, and in the second column are the values of the diameter (Δ) of an atom in the same units; in the third column is the number (n) of atoms normally in a mole-

cule, these being equal to $\frac{2d}{\Delta}$, and in the fourth column is the number (s) of molecules in contact with unit-surface which is one square inch, and one square centimeter, respectively, and since the molecules are spherical, $s = \frac{1}{d^2}$; the fifth column contains the values of the mass (m) of an atom, in pounds avoirdupois, and grams; the sixth column containing weight (w) of an atom, in the same units, this being equal to gm when g represents the terrestrial force or gravity, or—32.173 feet per second; in the seventh and eighth columns are the mass(M) and the weight(W) of a molecule normally composed of a number (n) of these atoms, these being simply the quantities in the fifth and sixth columns multiplied by n; in the ninth column of the first table is the density (δ) of an atom (and of all atoms, under my theory) this density being relative to that of water at temperature of maximum density, or 39° Fahrenheit, and in the corresponding column of the second table is the number (l) of normal molecular layers in 4041 cubic centimeters, of mixed hydrogen and oxygen resulting from the electrolysis of one grams of water in one cubic centimeter; it represents the number of layers in a parallelopiped having a base of one square centimeter and a length of 4041 centimeters, and is a factor in the expression in the electrochemical equivalent of water; in the tenth, eleventh and twelfth columns, respectively, are the values of the velocity of light (V_l); the fundamental orbital velocity $V_1 = 2\pi V_l$ for absolute temperature of 1° F, and the orbital velocity V_o for absolute temperature $T_o = 419.66$ or 32° Fahrenheit, it being equal to $T_o V_1$, and these three quantities are expressed in feet and centimeters, per second; in the thirteenth column is the number of molecules in a cubic inch and a cubic centimeter.

With the numerical values in these two tables all the equations set forth on preceding pages and also those to follow can be easily solved, and for convenience in computation the logarithm of each quantity is placed beneath it, the logarithm of each fractional value having the letter n appended to the mantissa.

The derivation of the electromagnetic, electrostatic, and electrochemical units in absolute measures of the C G S system, and also the strength of a magnetic pole, will now be set forth, these having been primarily derived from the kinetic energy (E_o) from a single layer of molecules in contact with one square centimeter of a solid surface, and having a thickness equal to the

ENGLISH UNITS.

Atmospheric Air	d Inch	Δ Inch	$N = 2.\frac{d}{\Delta}$	$s = \frac{1}{d^2}$ Square Inch	m Pound	$w = gm$ Pound
Pressure per square inch 14.730 pounds Temperature $T_o = 491°.66 = 32°$ Fahrenheit The Ether Density (D) Air $= 1$ $\frac{1}{1412 \times 10^{13}}$ 16.149984 n	$\frac{1}{73,585,000}$ 7.866790 n $\frac{1}{304.4}$ 2.483445 n	$\frac{1}{1273 \times 10^{19}}$ 22.104828 n Same	3460×10^{11} 14.539076 8364×10^{16} 19.922413	5415×10^{12} 15.733580 92,660 4.966890	$\frac{1}{9500 \times 10^{40}}$ 43.977754 n Same	$\frac{1}{2953 \times 10^{39}}$ 42.470263 n Same

$M = nm$ Pound	$W = gm$ Pound	Density of Atoms (δ) (Water $= 1$)	V_1 Feet per sec.	$V_1 = 2\pi V_1$ Feet per sec.	$V_o = T_o V_1$ Feet per sec.	Molecules in Cubic Inch
$\frac{1}{2746 \times 10^{25}}$ 29.438678 n	$\frac{1}{8534 \times 10^{24}}$ 27.931157 n	3964×10^{23} 26.567497	9839×10^{5} 8.992951	6182×10^{6} 9.791129	3039×10^{9} 12.482779	3984×10^{20} 23.600370
$\frac{1}{1136 \times 10^{21}}$ 24.055341 n	$\frac{1}{3530 \times 10^{19}}$ 22.547820 n	Same	Same	Same	6182×10^{6} 9.791129	28,205,600 7.450335

C G S Units.

Atmospheric Air	d Centimeter	Δ Centimeter	$n = 2\frac{d}{\Delta}$	$s = \frac{1}{d^2}$ per sq. cm.	m Gram	$w = gm$ Gram
Pressure per square centimeter	$\frac{1}{28{,}971{,}000}$	$\frac{1}{5012 \times 10^{18}}$	3460×10^{11}	8393×10^{11}	$\frac{1}{2095 \times 10^{38}}$	$\frac{1}{6516 \times 10^{36}}$
1035.7 dynes	$7.461964\ n$	$21.700002\ n$	14.539076	14.923928	$41.321084\ n$	$39.813593\ n$
Temperature						
$T_o = 491°.66 = 32°$ Fahrenheit						
The Ether	$\frac{1}{120}$	Same	8364×10^{16}	14,363	Same	Same
Density (D) Air = 1						
$\frac{1}{1412 \times 10^{12}}$	$2.078619\ n$		19.922413	4.157238		
$16.149984\ n$						

M Gram	$w = gm$ Gram	$l = \frac{4041}{d}$	V_1 cm. per sec.	$V_1 = 2\pi V_1$ cm. per sec.	$V_o - TV_1$ cm. per sec.	Molecules in Cu. Centimeter
$\frac{1}{6054 \times 10^{25}}$	$\frac{1}{1882 \times 10^{22}}$	1170×10^{8}	2999×10^{7}	1884×10^{8}	9264×10^{10}	2432×10^{19}
$26.782008\ n$	$25.274514\ n$	11.068345	10.476958	11.275139	13.966786	22.385892
$\frac{1}{2504 \times 10^{18}}$	$\frac{1}{7784 \times 10^{16}}$		Same	Same	1884×10^{8}	1,721,300
$21.398671\ n$	$19.891177\ n$				11.275139	6.235857

molecular diameter (d) expressed here in centimeters and directly from the normal atmospheric pressure (P_a) expressed in grams per square centimeter, the theoretical value whereof, which is 1035.2 [3.015038] having been derived through my several equations for P_a set forth on a preceding page, this value agreeing exactly with that determined experimentally.

The equivalent algebraic expression for P_a involving the mass (m) and the weight (w) of an atom, the mass (M) and weight (W) of a molecule composed of these atoms, and also the relative density (D) of the luminiferous ether, can be easily substituted in the following equations, thus showing the functions of the atoms of the molecules (in unit layer of the interface) in the development and propagation of electric and magnetic action.

The velocity of light (V_l) is 2999 x 10^7 centimeters per second correct to the fourth place, its logarithm being 10.476958, the number (s) of molecules in contact with one square centimeter, and which is designated by s, is equal to the inverse square of the molecular diameter (d), its value being 8393 x 10^{11} [14.923928] and the value of (l) is 1170 x 10^8 [11.068345.]

The following are the algebraic expressions for the aforesaid absolute units:

$$R_m = \frac{P_a}{d^2} V_l^2;(\kappa) \qquad E_m = \frac{P_a}{10d^2} V_l^2;(\iota) \quad e = \frac{E_m}{V_l} = \frac{P_a}{d^2} V_l;(\mu)$$

$$\frac{E_m}{e} = V_l;(\gamma) \quad e = \frac{E_m}{l} = \frac{P_a}{ld^2} V_l^2;(\phi) \quad I = \frac{2\pi}{g} E_m = \frac{2\pi P_a}{980.2d^2} V_l^2;(\chi)$$

$$S = \frac{I}{R_s^2};\ (\psi)$$

Using the numerical data aforesaid, a solution of equation (κ) gives 1109×10^6 as the number of absolute (C G S) units in R_m which, under my theory, represents the electromagnetic resistance called the "ohm", the value whereof as determined by the classical experiment of the British Association in 1862 is 1000×10^6. Equation (γ) gives for E_m which represents the electromagnetic unit of electromotive force (EMF) 1109×10^5 which is my theoretical number of units in the volt—the experimental value veing 1000×10^5—and therefore the unit of current (C) which is given through the equation $C = \frac{E_m}{R_m}$ and is called the "ampere", is equal to one-tenth of an absolute unit of the C G S system, and this is also the experimental value. Equation (μ) gives for the electrostatic unit of electromotive force, 0.000370 in absolute units, the ratio between E_m and e, as shown in equation (ν) being equal to the velocity of light,

which proves both theoretically and practically, the truth of the well-known hypothesis advanced by the late Professor J. Clerk Maxwell that "light" is an electromagnetic phenomenon and that electromagnetic action is propagated by waves through the luminiferous ether, in the same manner and with the same velocity as are luminous radiations. The value E given by equation (ϕ) is 0.0009476 which represents the weight, in grams, of water decomposed by electrolysis into the component gases hydrogen and oxygen in a "voltameter" by unit current per second, this being the well-known electrochemical unit from which the weight of the ions of all the chemical substances is determinable through multiplication through the atomic weight, of the chemical element or compound. My theoretical value of this unit agrees exactly with that experimentally determined by Kohlrausch—a most important fact as it serves as a check upon the determination of the other units.

The quantity represented by I, in the equation (χ) is the maximum total intensity of magnetic force, or the strength of pole, a solution of that equation giving 710,730 absolute units (dynes per square centimeter) as the value of this quantity when all the atoms of each and every molecule in contact with unit surface are affected, this being the highest possible magnetic permeability or the greatest number of lines of force in the unit surface of a magnetized body, the value of a line of force being one dyne per square centimeter—the maximum permeability in the case of soft iron being 17,500 lines as experimentally determined.

Saint Paul, Minnesota. To be continued.

General Index for Three Magazines. In last year, we issued a circular promising to print a general index of the ten volumes of the *Sidereal Messenger*, three volumes of *Astronomy* and *Astro-Physics* and fifteen volumes of POPULAR ASTRONOMY, at a price of $1.50 in paper covers or $2 50 per volume, in good library binding if 300 subscriptions could be secured to aid in the expense of publication. We received orders for less than 100 copies of the index, and so concluded that we could not afford to prepare it, although Professor E. C. Pickering, Director of Harvard College Observatory, had offered aid to the amount of $100.

When it was announced that the index would not be printed for the lack of funds Professor Pickering kindly solicited further aid for this work and promptly forwarded it to us. We now have sufficient guaranty for the publication, and the work of its preparation is going on. It will require several months to do this work thoroughly and accurately in view of other exacting duties; so subscribers are asked to be patient until the publication can be completed. We may further add that this new general index will cover sixteen volumes of POPULAR ASTRONOMY with the thirteen volumes of the other two publications named above, making in all twenty-nine volumes, iustead of twenty-eight as promised heretofore. The price of the index will not be increased. The form of the index will be the same as that recently published for the *Astrophysical Journal*.

PLANET NOTES FOR NOVEMBER, 1908.

Mercury is morning star, in perihelion Nov. 4, stationary in right ascension Nov. 6, and reaching greatest elongation west from the Sun 19° 19′, on Nov. 13. At this elongation the planet will be quite bright, easily picked up with the naked eye.

THE CONSTELLATIONS AT 9:00 P. M., NOVEMBER 1, 1908.

Venus will be in perihelion on the morning of Nov. 12. Her brightness continues to decrease from 91 on Nov. 1 to 73 on Dec. 1, owing to her increasing distance from the Earth. Her phase increases during the month from 0.7 to 0.8 of illuminated diameter. On Nov. 30 at 6 p. m. C. S. T. Venus and Mars will be in conjunction, the former being then 1° 17′ north of the latter.

Mars is in the same region of the sky with Venus as indicated in the preceding note, but is not in favorable position for study. The planet's apparent disk is now only 4″ in diameter.

Jupiter is also visible in the morning and may be found high in the sky toward the southeast at six o'clock.

Saturn is near the meridian at 9 o'clock in the evening in the constellation Pisces. There are no bright stars in this vicinity so that there is no difficulty in identifying the planet without telescopic aid. The rings of Saturn are easily seen as a single ring with the aid of a small telescope. Their plane is inclined only 5° to the line of sight during November so that the divisions of the ring cannot be distinguished.

Uranus may be found in the early evening in Sagittarius but is not in good position for study.

Neptune may be found with the aid of a large telescope in the constellation Gemini in the latter half of the night.

Occultations visible at Washington.

Date 1908	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle f'm N. °	EMERSION. Washington M.T. h m	EMERSION. Angle f'm N °	Duration h m
Nov. 1	ϕ Capricorni	5.3	5 12	54	6 30	269	1 18
4	33 Piscium	4.7	6 21	19	7 15	280	0 54
4	Piazzi o^h, I	6.0	9 13	81	10 20	209	1 07
6	Piazzi I^h, 249	6.5	14 13	87	15 14	222	1 01
7	85 Ceti	6.3	4 41	116	5 14	196	0 33
8	Mayer 136	5 9	13 21	106	14 25	210	1 04
8	Piazzi III^h 215	5.8	17 56	33	18 38	305	0 42
9	B.A.C. 1417	6.4	6 19	25	6 55	297	0 36
10	Piazzi V^h 184	6.5	10 32	104	11 33	221	1 01
11	B.A.C. 2238	5.8	19 05	153	19 46	224	0 41
12	82 Geminorum	6.3	19 47	88	20 53	302	1 06
26	B.A.C. 6465	6.4	5 03	52	6 06	292	1 03
26	B.A.C. 6479	6.4	6 00	82	7 06	260	1 06

COMET NOTES.

New Comet c 1908 (Morehouse)—A telegram from Prof. E. C. Pickering, received Sept. 3 announced the discovery of a comet upon a photograph, taken by Morehouse at the Yerkes Observatory on Sept. 1. The comet was described as having a long tail and as moving rapidly southeast or northwest. Its position as estimated from the photograph was

Sept. 1.361 Gr. M. T. $\alpha = 3^h\ 20^m$ $\delta = +66°15$.

The following more accurate positions have come to hand up the present writing;

Greenwich M.T.	R. A. h m s	Dec. ° ′ ″	Observer.	Place.
Sept. 2.7396	3 21 55.	+66 52 24	Fox	Williams Bay
3.4023	3 19 43.0	+67 14 42	Thiele	Copenhagen
3.6479	3 18 50.1	+67 23.2	Metcalf	Taunton
3.7032	3 18 41.	+67 24 57	Fox	Williams Bay
3.8421	3 18 13.9	+67 29 35	Aitken	Mt. Hamilton
4.6521	3 15 15.	+67 57 28	Fox	Williams Bay
4.8470	3 14 32.3	+68 03 59	Aitken	Mt. Hamilton
5.8705	3 10 21.2	+68 39 30	Aitken	Mt. Hamilton
14.5534	2 08 59.3	+73 45.6	Metcalf	Taunton

From the first, fifth and seventh of these observations Messrs. Einarsson and Meyer of the Berkeley Astronomicial Department have computed the following preliminary elements and ephemeris:

ELEMENTS

$T = 1909$ Jan. 5.702 Gr. M.T.
$\omega = 152° 04.'0$
$\Omega = 90\ 20.5$ } 1908.0
$i = 135\ 56.2$
$q = 1.1680$

CONSTANTS FOR THE EQUATOR 1908.0

$x = r\ [9.85648] \sin (151° 35.'5 + v)$
$y = r\ [9.98098] \sin (258\ 37.9 + v)$
$z = r\ [9.87703] \sin (183\ 57.2 + v)$

EPHEMERIS FOR GREENWICH MEAN MIDNIGHT.

1908		True α	True δ	log Δ	Brightness
Sept.	11.5	$2^h\ 38^m\ 02^s$	$+71°\ 57.'0$	0.2320	1.30
	12.5	2 30 12	72 31.4		
	13.5	2 21 31	73 05.1	0.2202	1.44
	14.5	2 11 54	73 37.8		
	15.5	2 01 18	74 09.2	0.2085	1.56
	16.5	1 49 37	74 38.9		
	17.5	1 36 48	75 06.4	0.1968	1.67
	18.5	1 22 46	75 31.1		
	19.5	1 07 31	75 52.5	0.1854	1.80
	20.5	0 51 06	76 10.0		
	21.5	0 33 36	76 23.0	0.1742	1.94
	22.5	0 15 10	76 30.7		
	23.5	23 56 02	76 32.7	0.1623	2.08
	24.5	23 36 28	76 28.6		
	25.5	23 16 48	76 18.0	0.1528	2.21
	26.5	22 57 21	76 00.8		
	27.5	22 38 27	75 36.9	0.1429	2.36
	28.5	22 20 21	75 06.3		
	29.5	22 03 14	74 29.4	0.1335	2.57
	30.5	21 47 14	73 46.6		
Oct.	1.5	21 32 25	72 58.4	0.1249	2.73
	2.5	21 18 48	72 05.0		
	3.5	21 06 23	$+71$ 06.9	0.1170	2.90

Brightness Sept. 3 = 1.00.

It will be seen from this Ephemeris the comet's course has been through the constellation Cepheus and that it is pointing toward Cygnus. Probably during October it will pass through the western part of Cygnus.

At present the comet is not visible to the naked eye and is not very conspicuous in a small telescope. One can see very little of the tail which the photographs are reported to show. At Goodsell Observatory we have had little opportunity to watch the comet and have as yet taken no measures or photographs. In the Harvard College Observatory Astronomical Bulletin No. 337 it is stated that a photograph taken by Rev. Joel H. Metcalf, of Taunton, Mass., on Sept. 14 with an exposure of an hour, shows that the comet is increasing in brightness and that it has a double tail which is irregular on the northern side.

Professor Pickering suggests that good photographs of Morehouse's comet, taken at intervals throughout the night, and in different longitudes, so that its changes may be followed continuously, will have much value. Doublets should be used with exposures of not less than an hour.

Elements and Ephemeris of Comet *c* 1908.—In the supplement to A. N. 4272, which came to hand Sept. 24, Mr. Hermann Kobold, of Kiel, gives elements of Comet *c*, depending upon an observation at Rome Sept. 3 and two at Copenhagen Sept. 4 and 5. These appear to be more accurate than those given in Lick Observatory Bulletin, since the ephemeris represents Mr. Metcalf's observation of Sept. 14 very much more closely. These indicate a still greater probable increase in the brightness of the comet, making it 3.6 times as bright on Sept. 30 as on Sept. 3.

CHART SHOWING THE APPARENT PATH OF COMET *c* 1908 FROM SEPT. 1 TO OCT. 3

ELEMENTS

$T = 1908$ Dec. 24.3175 Berlin M. T.
$\omega = 174° 13'.13$
$\Omega = 105 \quad 3.31$ } 1908.0
$i = 140 \quad 36.58$
$\log q = 9.96412$

EPHEMERIS FOR BERLIN MIDNIGHT.

1908		App. α h m s	App. δ ° ′	log r	log Δ	Brightness
Sept.	6	3 07 40	+69 00.5	0.2995	0.2187	1.2
	7	3 02 53	69 35.9			
	8	2 57 31	70 11.8			
	9	51 32	70 47.6			
	10	44 52	71 23.5	0.2884	0.1904	1.4
	11	37 29	71 59.6			
	12	29 14	72 35.4			
	13	20 13	73 10.1			
	14	2 09 49	73 43.8	0.2769	0.1615	1.7
	15	1 58 22	74 16.3			
	16	45 40	74 46.9			
	17	31 34	75 15.0			
	18	1 16 04	75 39.9	0.2651	0.1325	2.1
	19	0 59 04	+76 00.9			

EPHEMERIS FOR BERLIN MIDNIGHT, Continued.

1908		App. α h m s	App. δ ° ′	log *r*	log Δ	Brightness
Sept.	20	40 43	+76 17.2			
	21	21 01	76 27.8			
	22	0 00 21	76 31.9	0.2530	0.1039	2.5
	23	23 38 56	76 28.8			
	24	23 17 13	76 18.0			
	25	22 55 39	75 58.9			
	26	22 34 36	75 31.5	0.2405	0.0767	3.0
	27	22 14 30	74 55.7			
	28	21 55 32	74 12.1			
	29	21 37 55	73 20.8			
	30	21 21 51	+72 22.2	0.2277	0.0520	3.6

Search Ephemerides for the comet Tempel$_2$-Swift.—In A. N. 4269 Mr. E. Manbant of Paris gives elements of this periodic comet for the epoch Sept. 23, 1908, and search ephemerides extending from Aug. 29 to Nov. 1.

ELEMENTS OF COMET TEMPEL$_2$-SWIFT.

T = 1908 Sept 30.88236 Paris m. t.
M = 358° 37′ 56″.6
π = 43 59 57.5 } 1910.0
Ω = 290 18 40.3 }
i = 5 26 33.3 }
φ = 39 37 38.7
μ = 624″.6084
log a = 0.502933

SEARCH EPHEMERIS.

		R. A. h m s	Dec.	log *r*	log Δ
Oct.	4	7 20 57	+30° 10′.9	0.0622	9.8411
	5	25 10	+30 04.1		
	6	29 19	+29 51.0		
	7	33 24	+29 37.5		
	8	37 26	+29 23.7	0.0634	9.8431
	9	41 23	+29 09.5		
	10	45 16	+28 55.1		
	11	49 05	+28 40.4		
	12	52 51	+28 25.4	0.0655	9.8454
	13	7 56 32	+28 10.2		
	14	8 00 09	+27 54.8		
	15	3 42	+27 39.2		
	16	7 11	+27 23.4	0.0683	9.8478
	17	10 36	+28 07.4		
	18	13 57	+26 51.3		
	19	17 15	+26 35 1		
	20	20 28	+26 18.9	0.0719	9.8501
	21	23 37	+26 02.6		
	22	26 42	+25 46.2		
	23	29 44	+25 29.7		
	24	32 41	+25 13.2	0.0762	9.8524
	25	35 35	+24 56.7		
	26	38 25	+24 40.2		
	27	41 11	+24 23.7		
	28	43 53	+24 07.1	0.0812	9.8544
	29	46 32	+23 50.6		
	30	49 07	+23 34.2		
	31	51 38	+23 17.8		
Nov.	1	8 54 05	+23 01.5	0.0867	9.8562

If the comet's perilielion passage should occur eight days earlier or eight days later than calculated, its position on the first and last of the above dates would be as follows:

	T = Sept 22.88				T = Oct. 8.88			
	R.A.		Dec.		R.A.		Dec.	
Oct. 4	$7^h\ 45^m\ 37^s$		$+27°\ 30'.1$		$6^h\ 47^m\ 11^s$		$+33°\ 47'.8$	
Nov. 1	9 10 38		+20 13.4		9 32 25		+26 46.3	

The search for the comet should therefore be extended along a line about 15° long running northwest and southeast through the positions given in the ephemeris. The comet's motion will be southeastward from the shoulders of the Gemini through the constellation Cancer.

Search Ephemeris for Halley's Comet.—Mr. F. E. Seagrave sends the following positions calculated by him for Halley's comet, for the dates which will fall in the dark of the Moon in October and November. It is greatly to be hoped that some one will be able to pick up the comet this year although its distance from us is greater than that of Jupiter.

1908	α h m s	δ	log r	log Δ
Oct. 19	6 40 43	+11° 50′ 15″	0.8071	0.7832
23	6 39 39	+11 45 26	0.8050	0.7765
27	6 38 22	+11 40 49	0.8029	0.7697
Nov. 19	6 26 57	+11 19 42	0.7904	0.7329
23	6 24 13	+11 17 16	0 7882	0.7271
27	6 21 18	0 11 15 17	0.7859	0.7213

Comet *c* 1908. A telegram has been received at this Observatory from Professor R. T. Crawford at Berkeley, Cal., stating that the following elements and ephemeris of Morehouse's comet have been computed by Einarsson and Meyer from observations on Sept. 3, 11 and 18.

ELEMENTS

Time of perihelion passage = (T) = Dec. 25.81 G. M. T.		
Perihelion minus node	(ω)	171° 31′
Longitude of node	(Ω)	103° 05′
Inclination	(i)	140° 10′
Perihelion distance	(q)	0.946

EPHEMERIS

G. M. T.	R. A.	Dec.	Light
Sep. 23.5	$23^h\ 40^m\ 21^s$	+76° 29′	2.43
27.5	22 16 49	75 00	
Oct. 1.5	21 09 50	71 28	
5.5	20 44 02	66 23	3.95

ASTRONOMICAL BULLETIN, No. 338,
Harvard College Observatory,
Sept. 22, 1908, Cambridge, Mass.

VARIABLE STARS.

The Variable Star 31. 1907. (U Geminorum type) was found by Mr. L. Campbell to be bright, magn. 11.3 on Friday, Aug. $28^d\ 19^h\ 49^m$ G. M. T. A cable message from Kiel received September 1, announced that it was also found to be bright by Hartwig. Photographs taken at Cambridge give the following results.

Date		J. D	Expos. m	Magn.
1908				
August	23	8177.857	10	<13.2
	28	8182.836	17	10.6
	27	8183.723	15	10.7
	27	8183.842	60	10.6
	27	8183.874	15	10.5
	30	8184.789	15	10.8
	31	8185.835	15	10.7
	31	8185.841	60	10.7

The scale of magnitude is that given in the seventh column of Table I of H. C. 138.

ASTRONOMICAL BULLETIN, No. 331.
Harvard College Observatory,
Sept. 2, Cambridge, Mass.

Elements of the Variable Stars 165 and 167.1907 Leonis.—In *A.N.* 4266 Mr. M. Luizet gives elements of these two variables depending upon his own observations during 1908. For 165.1907 he finds from four observed minima the elements

Minimum = 1908 April 22 $10^h\ 10^m$ (Paris M. T.) $+1^d\ 16^h\ 28.^m3$ E
= 2418054.424 " " $+1.6863$ E .

The time occupied by the change of light is about $4^h\ 50^m$, the brightness at maximum about 9.3 mag. and that at minimum 11.2 mag.

For 167.1907 the elements determined graphically from observations covering two maxima and two minima are

Maximum = 2418061 $+59^d$ E
= 1908 April 29 $+59^d$ E .

The variation is continuous, the brightness increasing during 28 days and diminishing for about 31 days. The range of magnitude is from 7.9 to 9.6.

New Variable 15.1908 Bootis.—In the Comptes Rendus Vol. 147, page 23 Mr. J. Baillaud calls attention to a faint variable found upon the plates taken for the Paris photographic charts. Its position for 1900.0 is

$$\alpha = 14^h\ 41^m\ 31.^s80 \quad \delta = +23^\circ\ 43'\ 59.''7$$

the star is of the δ Cephei type and the range of variation is between magnitudes 12.8 and 14.5. The increase of light lasts $1^h\ 41^m$ and is shorter than the decrease, which lasts $6^h\ 13^m$ or $10^h\ 10^m$.

New Variable 16.1908 Vulpeculæ.—In *A.N.* 4270 Professor H. H. Turner announces the discovery of a new variable by Mr. T. H. Astbury, of Wallingford, England. The star is BD $+22^\circ$ 3647 and its position for 1900.0 is

$$\alpha = 19^h\ 13^m.4 \quad \delta = +22^\circ\ 16'.$$

The magnitude is about 7.0. On July 25 it was fainter than usual and on Aug. 3 it was fully a magnitude fainter than on Aug. 2.

New Variable 17.1908 Persei.—In *A.N.* 4271 Mr. S. Enebo calls attention to the star BD $+50^\circ$ 961. Its magnitude is given in the BD as 9.5, but according to several observations around Nov. 2, 1907, it was less than 11.5. From Feb. 28 to April 21, 1908 it was steady at about magnitude 10.5. On Aug. 5, 15 and 16, 1908 it was equal to BD $+50^\circ$ 959, magnitude 9.5. The star is red in color and the period is apparently long.

Mr. M. Ebell gives the position of the star from the A. G. Zone catalogue as

1900.0 $\alpha = 4^h\ 9^m\ 1.^s46$ $\delta = +50^\circ\ 22'\ 33.''0$
1855.0 4 5 39. 28 +50 15 27. 0

The star was observed by T. E. Espin on Nov. 9, 1895 as of magnitude 8.8. He noted the color as R R and the spectrum as of Type IV.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei		RX Cephei		λ Tauri		RW Monoc.		R Canis Maj	
d	h	d	h	d	h	d	h	d	h
Nov. 2	5	Nov. 8	10	Nov. 23	7	Nov. 12	10	Nov. 12	4
4	17	Algol		27	6	14	8	13	7
7	5	Nov. 1	6	RW Tauri		16	6	14	10
9	17	4	2	Nov. 1	20	18	4	15	14
12	5	6	23	4	14	20	1	16	17
14	17	9	20	7	9	21	23	17	20
17	4	12	17	10	3	23	21	18	23
19	16	15	14	12	22	25	19	20	3
22	4	18	10	15	16	27	16	21	6
24	16	21	7	18	10	29	14	22	9
27	4	24	4	21	5	RU Monoc.		23	12
29	16	27	1	23	23	Nov. 1	5	24	16
Z Persei		29	22	26	18	2	3	25	19
Nov. 1	1	RT Persei		29	12	3	0	26	22
4	2	Nov. 1	7	RV Persei		3	22	28	1
7	3	2	3	Nov. 2	15	4	19	29	5
10	4	3	0	4	15	5	17	30	8
13	6	3	20	6	14	6	14	Y Camelop.	
16	7	4	16	8	14	7	12	Nov. 4	1
19	9	5	13	10	13	8	9	7	8
22	10	6	9	12	12	9	7	10	15
25	11	7	6	14	12	10	4	13	23
28	13	8	2	16	11	11	2	17	6
RY Persei		8	22	18	10	11	23	20	13
Nov. 5	1	9	19	20	10	12	21	23	21
11	22	10	15	22	9	13	18	27	4
18	19	11	11	24	8	14	16	30	11
25	16	12	8	26	8	15	13	RR Puppis	
RZ Cassiop.		13	4	28	7	16	11	Nov. 3	15
Nov. 2	7	14	1	30	7	17	8	10	1
3	11	14	21	RW Persei		18	6	16	11
4	16	15	17	Nov. 3	11	19	4	22	22
5	21	16	14	16	16	20	1	29	8
7	1	17	10	29	20	20	23	V Puppis	
8	6	18	7	RS Cephei		21	20	Nov. 1	6
9	11	19	3	Nov. 12	7	22	18	2	17
10	15	19	23	24	17	23	15	4	4
11	20	20	20	RW Geminorum		24	13	5	14
13	1	21	16	Nov. 2	5	25	10	7	1
14	6	22	12	5	2	26	8	8	12
15	10	23	9	7	23	27	5	9	23
15	10	24	5	10	20	28	3	11	10
16	15	25	2	13	16	29	0	12	21
17	20	25	22	16	13	29	22	14	8
19	0	26	18	19	10	30	19	15	19
20	5	27	15	22	7	R Canis Maj.		17	6
21	10	28	11	25	4	Nov. 1	22	18	17
22	14	29	8	28	0	3	2	20	4
23	19	30	4	30	21	4	5	21	14
25	0	λ Tauri		RW Monoc.		5	8	23	1
26	4	Nov. 3	13	Nov. 2	22	6	11	24	12
27	9	7	12	4	19	7	15	25	23
28	14	11	11	6	17	8	18	27	10
29	19	15	9	8	15	9	21	28	21
30	23	19	8	10	13	11	0	30	8

Minima of Variable Stars of the Algol Type.—Continued.

S Cancri

	d	h
Nov.	7	2
	16	14
	26	1

S Velorum

Nov.	3	1
	8	23
	14	21
	20	20
	26	18

RR Velorum

Nov.	2	3
	3	23
	5	20
	7	16
	9	13
	11	9
	13	6
	15	2
	16	23
	18	19
	20	16
	22	12
	24	9
	26	5
	28	2
	29	22

SS Carinæ

Nov.	3	23
	7	7
	10	14
	13	21
	17	4
	20	12
	23	19
	27	2
	30	9

Z Draconis

Nov.	1	11
	3	20
	4	4
	5	13
	7	21
	8	6
	9	14
	10	23
	12	8
	13	16
	15	1
	16	9
	17	18
	19	2
	20	11
	21	20
	23	4
	24	13
	25	21
	27	6
	28	14
	29	23

R Aræ

	d	h
Nov.	5	5
	9	15
	18	12
	22	22
	27	8

U Ophiuchi

Nov.	1	8
	2	4
	3	0
	3	21
	4	17
	5	13
	6	9
	7	5
	8	1
	8	21
	9	17
	10	14
	11	10
	12	6
	13	2
	13	22
	14	18
	15	14
	16	11
	17	7
	18	3
	18	23
	19	19
	20	15
	21	11
	22	7
	23	4
	24	0
	24	20
	25	16
	26	12
	27	8
	28	4
	29	0
	29	21
	30	17

Z Herculis

Nov.	3	0
	7	0
	10	23
	14	23
	18	23
	22	23
	26	23
	30	23

RS Sagittarii

Nov.	3	1
	5	11
	7	21
	10	7
	12	17
	15	3
	17	13
	19	23

RS Sagittarii

	d	h
Nov.	22	9
	24	19
	27	5
	29	15

V Serpentis

Nov.	3	14
	7	1
	10	12
	13	23
	17	10
	20	21
	24	7
	27	18

RX Herculis

Nov.	1	7
	2	4
	3	2
	3	23
	4	20
	5	18
	6	15
	7	12
	8	10
	9	7
	10	4
	11	2
	11	23
	12	20
	13	18
	14	15
	15	13
	16	10
	17	7
	18	5
	19	2
	19	23
	20	21
	21	18
	22	15
	23	13
	24	10
	25	7
	26	5
	27	2
	27	23
	28	21
	29	18
	30	15

SX Sagittarii

Nov.	1	10
	3	12
	5	14
	7	16
	9	18
	11	20
	13	21
	15	23
	18	1
	20	3

SX Sagittarii

	d	h
Nov.	22	5
	24	7
	28	10
	30	12

RR Draconis

Nov.	3	17
	6	13
	9	9
	12	5
	15	1
	17	21
	20	17
	23	13
	26	9
	29	4

U Scuti

Nov.	1	6
	2	5
	3	4
	4	2
	5	1
	6	0
	6	23
	7	22
	8	21
	9	20
	10	19
	11	18
	12	13
	13	16
	14	15
	15	13
	16	12
	17	11
	18	10
	19	9
	20	8
	21	7
	22	6
	23	5
	24	4
	25	3
	26	2
	27	0
	27	23
	28	22
	29	21
	30	20

RX Draconis

Nov.	2	15
	4	13
	6	10
	8	8
	10	5
	12	3
	14	0
	15	21
	17	19
	19	16
	21	14

RX Draconis

	d	h
Nov.	23	11
	25	9
	27	6
	29	4

RV Lyræ

Nov.	3	12
	7	2
	10	16
	14	7
	17	21
	21	11
	25	2
	28	16

U Sagittae

Nov.	3	9
	6	19
	10	4
	13	13
	16	22
	20	7
	23	16
	27	1
	30	10

SY Cygni

Nov.	2	12
	8	12
	14	12
	20	12
	26	13

WW Cygni

Nov.	2	16
	6	0
	9	7
	12	15
	15	23
	19	6
	22	14
	25	22
	29	5

SW Cygni

Nov.	2	18
	7	8
	11	21
	16	11
	21	1
	25	15
	30	4

VW Cygni

Nov.	7	22
	16	8
	24	19

UW Cygni

Nov.	1	16
	5	3
	8	14
	12	1
	15	12
	18	22
	22	9
	25	20
	29	7

Minima of Variable Stars of the Algol Type.—Continued.

W Delphini		VV Cygni		VV Cygni		VV Cygni		VV Cygni
d	h	d	h	d	h	d	h	d h
Nov. 4	19	Nov. 2	9	Nov. 11	6	Nov. 20	3	Nov. 28 23
9	15	3	21	12	17	21	14	30 11
14	10	5	8	14	5	23	1	
19	5	6	20	15	16	24	13	
24	1	8	7	17	4	26	0	UZ Cygni
28	20	9	18	18	15	27	12	Nov. 2 0

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

Y Aurigæ		W Carinæ		R Triang. Austr.		X Sagittarii		U Aquilæ	
d	h	d	h	d	h	d	h	d	h
(−0	18)	(−1	0)	(−1	0)	(−2	22)	(−2	4)
Nov. 3	7	Nov. 1	9	Nov. 2	9	Nov. 6	9	Nov. 1	19
7	4	5	18	5	18	13	9	8	19
11	0	10	3	9	4	20	10	15	19
14	21	14	11	12	13	27	10	22	20
18	17	18	20	15	22			29	20
22	14	23	5	19	8	Y Ophiuchi			
26	11	27	14	22	17	(−6	5)	U Vulpeculæ	
30	7	31	23	26	2	Nov. 1	14	(−2	3)
		S Muscæ		29	12	18	17	Nov. 8	3
T Monoc.		(−3	11)			W Sagittarii		16	3
(−7	23)	Nov. 8	15	S Triang. Austr.		(−3	0)	24	2
Nov. 4	12	18	7	(−2	2)	Nov. 5	7	SU Cygni	
		27	22	Nov. 2	5	12	21	(−1	7)
W Geminorum		T Crucis		8	12	20	12	Nov. 2	10
(−2	22)	(−2	2)	14	20	28	2	6	6
Nov. 7	10	Nov. 7	1	21	4			10	2
15	8	13	19	27	12	Y Sagittarii		13	23
23	6	20	12			(−2	2)	17	19
		27	6	S Normæ		Nov. 6	2	21	15
ζ Geminorum		R Crucis		(−4	10)	11	21	25	12
(−5	0)	(−1	10)	Nov. 1	19	17	15	29	8
Nov. 9	23	Nov. 2	13	11	13	23	10		
20	3	8	9	21	7	28	4	η Aquilae	
30	7	14	4	30	1			(−2	6)
		20	0			U Sagittarii		Nov. 4	8
RW Cassiop.		25	20	RV Scorpii		(−2	23)	11	13
(−9	12)	S Crucis		(−1	10)	Nov. 7	13	18	17
Nov. 20	20	(−1	12)	Nov. 5	3	14	7	25	21
		Nov. 2	21	11	5	21	1		
V Carinæ		7	14	17	6	27	18	S Sagittae	
(−2	4)	12	6	23	8			(−3	10)
Nov. 1	3	16	23	29	9	β Lyræ		Nov. 1	21
7	20	21	15			(−3	2)	10	6
14	12	26	8			(−3	7)	18	15
21	5	W Virginis		RV Ophiuchi		Nov. 6	22	27	0
27	22	(−8	5)	Minimum.		13	14	X Vulpeculæ	
		Nov. 6	6	Nov. 3	6	19	20	(−2	1)
T Velorum		23	13	6	22	26	12	Nov. 1	16
(−1	10)	V Centauri		10	15			7	23
Nov. 1	1	(−1	11)	14	7	κ Pavonis		14	7
5	16	Nov. 4	11	18	0	(−1	7)	20	15
10	7	9	23	21	16	Nov. 1	20	26	22
14	23	15	11	25	9	10	22	V Vulpeculae	
19	14	20	23	29	1	20	1	Minimum	
24	5	26	11			29	3	Nov. 17	3
28	21								

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

X Cygni		WZ Cygni		TX Cygni		δ Cephei		RS Cassiop.	
d	h	d	h	d	h	d	h	d	h
(−6	19)	Nov. 9	3	Nov. 4	11	Nov. 18	23	(−1	19)
Nov. 6	14	10	7	19	4	24	7	Nov. 5	20
22	23	11	11	VY Cygni		29	16	12	3
T Vulpeculae		12	15	(−2	14)	V Lacertae		18	10
(−1	10)	13	19	Nov. 3	7	(−0	17)	24	17
Nov. 4	9	15	0	19	1	Nov. 5	12	RV Cassiop.	
8	20	16	4	26	21	10	12	(−7	10)
13	6	17	8	VZ Cygni		15	11	Nov. 7	0
17	16	18	12	(−2	12)	20	11	19	4
22	3	19	16	(−3	6)	25	11	31	7
26	13	20	20	Nov. 10	12	30	10	Y Lacertae	
WZ Cygni		22	0	15	12	X Lacertae		(−1	10)
Alternate		23	4	20	6	Minimum		Nov. 4	4
Minima		24	8	25	6	Nov. 4	13	8	12
Nov. 2	3	25	12	29	23	10	0	12	19
3	7	26	16	δ Cephei		15	11	17	3
4	11	27	20	(−1	10)	20	21	21	10
5	15	29	0	Nov. 2	20	26	8	25	18
6	19	30	4	8	5			30	1
7	23			13	14				

Approximate Magnitudes of Variable Stars on September 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.
X Androm.	0	10.8	+46	27	8.8 *i*	R Urs. Maj.	10	37.6	+69	18	7.5 *i*
T Androm.		17.2	+26	26	<13.5	T Can. Ven.	12	25.2	+32	3	11.0*d*
T Cassiop.		17.8	+55	14	8.0 *i*	T Urs. Maj.		31.8	+60	2	8.0 *i*
R Androm.		18.8	+38	1	7.7	RS Urs. Maj.		34.4	+59	2	10.3 *i*
U Cassiop.		40.8	+47	43	<13.5	S Urs. Maj.		39.6	+61	38	7.5 *i*
RW Androm.		41.9	+32	8	10.8*d*	R Can. Ven.	13	44.6	+40	2	10.8 *i*
W Cassiop.		49.0	+58	1	9.4	Z Bootis	14	1.7	+13	59	13.4*d*
RX Androm.		58.9	+40	46	12.0	U Urs. Min.		15.1	+67	15	9.8 *i*
Z Ceti	1	1.6	−	2	1	10.0 *i*	S Bootis		19.5	+54	16	12.4*d*
U Androm.		9.8	+40	11	<13.0	V Bootis		25.7	+39	18	8.0 *i*
S Piscium		12.4	+	8	24	<13.2	R Camelop.		25.1	+84	17	13.0*d*
S Cassiop.		12.3	+72	5	9.8*d*	R Bootis		32.8	+27	10	7.6*d*
U Piscium		17.7	+12	21	<13.0	U Bootis		49.7	+18	6	11.5*d*
R Piscium		25.5	+	2	22	11.8	RT Librae	15	0.8	−18	21	13.6*d*
RU Androm.		32.8	+38	10	10.0	T Librae		5.0	−19	38	<13.0
S Arietis		59.3	+12	3	13.0	Y Librae		6.4	−	5	38	11.6 *i*
W Androm.	2	11.2	+43	50	8.2	S Librae		15.6	−20	2	7.8
Z Cephei		12.8	+81	13	9.5 *i*	S Serpentis		17.0	+14	40	9.0
o Ceti		14.3	−	3	26	5.5 *i*	S Coronae		17.3	+31	44	12.8*d*
R Ceti		20.9	−	0	38	10.2	RS Librae		18.5	−22	33	7.5
U Ceti		28.9	−13	35	9.8	RU Librae		27.7	−14	59	11.7*d*
R Trianguli		31.0	+33	50	11 2	X Librae		30.4	−20	50	11.0 *i*
T Arietis		42.8	+17	6	8.9	S Urs. Min.		33.4	+78	58	10.1*d*
Y Persei	3	20.9	+43	50	8.7	U Librae		36.2	−20	52	12.0 *i*
R Persei		23 7	+35	20	12.4*d*	Z Librae		40.7	−20	49	12.0 *i*
T Camelop.	4	30.4	+65	57	12.4	R Coronae		44.4	+28	28	6.1
R Aurigae	5	9.2	+53	28	13.0	X Coronae		45.2	+36	35	7.9 *i*
U Orionis		49.9	+20	10	10.0*d*	V Coronae		46.0	+39	52	12.0*d*
S Lyncis	6	35.9	+58	0	9.0 *i*	R Serpentis		46.1	+15	26	8.8*d*
R Lyncis		53.0	+55	28	13.0 *i*	R Librae		47.9	−15	56	10.0 *i*
X Urs. Maj.	8	33.7	+50	30	13.8*d*	RR Librae		50.6	−18	1	13.0
Y Draconis	9	31.1	+78	18	11.2*d*	Z Coronae		52.2	+29	32	9.0 *i*

Approximate Magnitudes of Variable Stars on Aug. 1, 1908—Con.

Name.	R. A. 1900.	Decl. 1900.	Magn.	Name.	R. A 1900	Decl. 1900	Magn.
	h m	° ′			h m	°	
RZ Scorpii	15 58.6	−23 50	8.0 *i*	U Lyrae	19 16.6	+37 42	<13.0
Z Scorpii	16 0.1	−21 28	11.4*d*	T Sagittae	17.2	+17 28	9.8*d*
R Herculis	1.7	+18 38	13.0*d*	TY Cygni	29.8	+28 6	9.8 *i*
RR Herculis	1.5	+50 46	8.0	R Cygni	34.1	+49 58	9.4*d*
U Serpentis	2.5	+10 12	12.2*d*	RV Aquilae	35.9	+ 9 42	13 0*d*
X Scorpii	2.7	−21 16	12.5*d*	RT Cygni	40.8	+48 32	10.0*d*
W Scorpii	5.9	−19 53	10.6	X Aquilae	46.5	+ 4 13	12.0 *i*
RX Scorpii	5.9	−24 38	11.7*d*	χ Cygni	46.7	+32 40	9.7*d*
RU Herculis	6.0	+25 20	8.3 *i*	RR Aquilae	52.4	− 2 11	11.0*d*
R Scorpii	11.7	−22 42	<13.5	RS Aquilae	53.7	− 7 9	13.0
S Scorpii	11.7	−22 39	9.5 *i*	Z Cygni	58.6	+49 46	10.6 *i*
W Coronae	11.8	+38 3	9.8*d*	SY Aquilae	20 2.3	+12 39	11.5*d*
W Ophiuchi	16.0	− 7 28	11.7*d*	S Cygni	3.4	+57 42	13.9
V Ophiuchi	21.2	−12 12	9 0 *i*	R Capricorni	5.7	−14 34	<13.5
U Herculis	21.4	+19 7	7.5 *i*	S Aquilae	7.0	+15 19	11.3*d*
Y Scorpii	23.8	−19 13	11.2*d*	RU Aquilae	8.0	+12 42	<13.6
SS Herculis	28.0	+ 7 3	12.0*d*	W Capricorni	8.6	−22 17	<13.6
W Herculis	31.7	+37 32	8.0 *i*	Z Aquilae	9.8	− 6 27	11.6*d*
R Draconis	32.4	+66 58	12.6*d*	RS Cygni	9.8	+38 28	8.0
S Herculis	47.4	+15 7	9.2 *i*	R Delphini	10.1	+ 8 47	9.1*d*
RV Herculis	56.8	+31 22	13.2	RT Capricorni	11.3	−21 38	8.0
R Ophiuchi	17 2.0	−15 58	10.2 *i*	SX Cygni	11.6	+30 46	10.0
RT Herculis	6.8	+27 11	<13.0	U Cygni	16.5	+47 35	8.1*d*
Z Ophiuchi	14.5	+ 1 37	7.8 *i*	RW Cygni	25.2	+39 39	8.8*d*
RS Herculis	17.5	+23 1	7.8 *i*	RU Capricorni	26.7	−22 2	<13.0
RU Ophiuchi	28.5	+ 9 30	9.2 *i*	Z Delphini	28.1	+17 7	<13.5
RS Ophiuchi	44.8	− 6 40	11.2	ST Cygni	29.9	+54 38	9.6*d*
RT Ophiuchi	51.8	+11 11	<13.6	Y Delphini	36.9	+11 31	<13.7
RY Herculis	55.4	+19 29	10.5 *i*	S Delphini	38.5	+16 44	9.0
V Draconis	56.3	+54 53	<13.0	T Delphini	40.7	+16 2	12.0*d*
T Herculis	18 5.3	+31 0	11.0	V Aquarii	41.8	+ 2 4	8.0
W Draconis	5.4	+65 56	<13.5	W Aquarii	41.2	− 4 27	9.4 *i*
X Draconis	6.8	+66 8	<13.5	V Delphini	43.2	+18 58	11.0*d*
RY Ophiuchi	11.6	+ 3 40	1.22*d*	T Aquarii	44.7	− 5 31	8.0
W Lyrae	11.5	+36 38	8.8*d*	RZ Cygni	48.5	+46 59	9.1*d*
SV Herculis	22.3	+24 58	11.0*d*	X Delphini	50.3	+17 16	10.1 *i*
T Serpentis	23.9	+ 6 14	13.0	— Delphini	50.3	+17 13	13.0
RZ Herculis	32.7	+25 28	8.5 *i*	R Vulpeculae	59.9	+23 26	11.4*d*
X Ophiuchi	33.6	+ 8 44	8.3*d*	X Cephei	21 3.6	+82 40	10.0 *i*
RY Lyrae	41.2	+34 34	13.0	R Equulei	8.4	+12 23	8.8 *i*
RW Lyrae	42.1	+43 32	13.1	T Cephei	8.2	+68 5	7.5*d*
Z Lyrae	56.0	+34 49	12.0*d*	RR Aquarii	9.8	− 3 19	8.0 *i*
RX Lyrae	50.4	+32 42	13.0 *i*	X Pegasi	16.3	+14 2	11.4*d*
ST Sagittarii	55.9	−12 54	<14.0	S Cephei	36.5	+78 10	8.3*d*
RT Lyrae	57.8	+37 22	11.0 *i*	RU Cygni	37.3	+53 52	8.0*d*
R Aquilae	19 1.6	+ 8 5	10.0 *i*	RR Pegasi	40.0	+24 33	12.5*d*
V Lyrae	5.2	+29 30	<14.0	V Pegasi	56.0	+ 5 38	10.0 *i*
RX Sagittarii	8.7	−18 59	12.4*d*	RT Pegasi	59.8	+34 38	11.0 *i*
RW Sagittarii	8.1	−19 2	8.9	Y Pegasi	22 6.8	+13 52	12.0*d*
S Lyrae	9.1	+25 50	<13.6	RS Pegasi	7.4	+14 4	12. 8
RS Lyrae	9.3	+33 15	13 4	S Lacertae	24.6	+39 48	11.4*d*
RU Lyrae	9.1	+41 8	11.0 *i*	R Lacertae	38.8	+41 51	8.0 *i*
U Draconis	9.9	+67 7	13.3*d*	RW Pegasi	59.2	+14 46	10.3*d*
W Aquilae	10.0	− 7 13	11.4*d*	R Pegasi	23 1.6	+10 0	9.2 *i*
T Sagittarii	10.5	−17 9	8.3*d*	V Cassiop.	7.4	+59 8	12.6*d*
RY Sagittarii	10.0	−33 42	7.0	Z Cassiop.	28.8	+48 16	10.5*d*
R Sagittarii	10.8	−19 29	10.5*d*	ST Androm.	33.8	+35 13	11.0 *i*
RT Aquilae	33.3	+11 30	11.6*d*	R Cassiop.	53.3	+50 50	8.0 i
S Sagittarii	13.6	−19 12	11.5*d*	Z Pegasi	55.0	+25 21	11.2 *i*
Z Sagittarii	13.8	−21 7	10.0*d*	Y Cassiop.	58.2	+55 7	10.4*d*

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign $<$, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Whiteside, Taft and Harvard Observatories.

GENERAL NOTES.

Brilliant Meteorite. N. Currean Jr., of New Bedford, Mass., observed a brilliant meteorite September 4, 1908, at 8^h 29^m, Eastern Standard time. Two person were with him, at the time, on the roof of a house watching an auroral display, when this meteorite made its appearance in the vicinity of θ Ursæ Majoris and disappeared near the star Capella in Auriga which was close to the horizon in a northwest direction. Its motion was slow, and its color whitish yellow and its train was well marked. It was seen to explode into many fragments of a bluish color, but their fall to the ground could not be observed neither could any sound be heard at the time of the explosion because of the noise in the streets near by.

The train was in view for about twelve seconds of time.

Manora Observatory in Lussinpiccolo (Austria) has been purchased by a private party who plans to continue astronomical work under the direction of Herr Brenner as heretofore. The observatory will be moved 100 meters north of its present place to a permanent position, and the work of the Observatory will be pertaining to the planets.

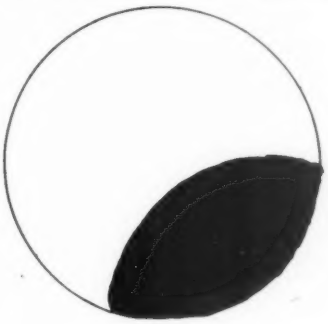
One Satellite of Jupiter Occults Another. A. Thos. G. Apple director of the Daniel Scholl Observatory, Franklin and Marshall College Lancester, Pa., made an interesting observation on the evening of March 16, 1908. It was reported August 21, 1908.

In watching the eclipse of Jupiter's second satellite, it was seen to reappear about ten seconds of arc from the first satellite. The two satellites were observed to approach each other and when in conjunction occultation took place. The seeing was good, for while ω Leonis could be separated with a 11.5-inch telescope of the Observatory, the two satellites could not be separated.

The Solar Eclipse of June 28, 1908. The most favorable land view of the solar eclipse of June 28 last was from the central plains of Florida, where for nearly four minutes the interesting annular phase was visible over a pathway about eighty-six miles in width. Near 11 A. M. when the Sabbath bells were tolling, and prayer and preaching had chief attention in the scattered cities, a strange gloom glided from over the Gulf, and dissolving the shadows of the steeples gave to the landscape an aspect differing essentially from that of sunrise, sunset or a merely clouded sky. In each of these cases the upper air is brilliantly illuminated, whereas an eclipse dims even the topmost vapors. Only about one-fourteenth of full sunlight was emitted by the slender rim of the solar disk that encircled the dark Moon. That an eclipse may be thus central and not total is a vivid demonstration of the varying distance of the Earth's satellite. Were it in perigee or the nearest point of the lunar orbit its dark shadow would have swept

over our globe, and in many places, the eclipse would have been total; but in the recent case, being near apogee, it was about thirty miles more distant, and the shadow terminated several thousand miles above the surface. Thus, though the June Sun had almost its least diameter of 31′ 34″ the apogean Moon was insufficient to cover it.

Nine degrees north and forty degrees west of Florida, our view of the phenomenon was an obscuration of the southwest portion of the early Sun. Owing to a lunar parallactic effect, or the different positions the Moon



seems to occupy in the heavens when observed from localities far apart, the two conspicuous spots on the Sun's disk were not encroached upon, as elsewhere, though nearly three-tenths of it were hidden by the invading shadow. As the dark concavity increased and then decreased it was easy to realize the progress of our satellite between its primary and the great luminary.

At a few minutes past eight the final trace of dimness disappeared on the lower limb of the Sun, the entire phase having lasted one hour and thirty-seven minutes.

ROSE O'HALLORAN.

San Francisco, Sept. 7, 1908.

An Aurora which was very unusual was observed here on Friday night, Sept. 4, 1908. The display continued from the time darkness set in until at least after midnight. The entire northern and eastern part of the heavens, from the horizon to the zenith was luminous with the light of the streamers. The display commenced in the northern sky, circling around towards the northwest, and then as the night advanced, gradually moved eastwards until by midnight, they were coming from due east. Some of the streamers coursed southwards almost as far as the planet Saturn, though none that I observed actually reached the planet. The light was flashed in broad beams resembling the flashes from a distant flashlight, and the beams were from ten to one hundred degrees of sky-space in length. At times many of them were flashing simultaneously, crossing and recrossing one another. Fully one-third of the sky was luminous at times by this display; and stars as bright as those of the second magnitude were obscured by the light. I do not remember having observed the extinction of any first magnitude stars, partly because not many were in the near neighbor-

hood of the aurora,—Capella had arisen, and although many other stars were invisible during the brighter portion of the illumination, still at no time was Capella hidden from sight. All of the principal stars of Cassiopeia were hidden very often; as were also the North Star, the principal stars of Ursa Major and Ursa Minor, the brighter stars of Perseus, Andromeda, and other constellations towards the north. Algol too was often hidden, and even as far south as Aries the bright stars suffered extinction quite frequently. I never remember having observed a similar display.

On the 14th inst., using a four-inch refracting telescope I observed four large spots on the sun; and in the southwestern quadrant a fairly-well dispersed group of spots was very visible. On the 20th instant I observed no fewer than seven large spots. The central one, (and it was almost exactly in the center of the sun's visible (surface was accompanied by a large number of much smaller spots. The largest spot was in that group, and comparing it as well as my memory will permit, with others observed at other times, and which were measured, I would say it must have been twenty or twenty-five thousand miles in length. We have had very poor skies here lately, the Sun struggling to makes its appearance, and then succeeding but imperfectly, and the stars so faint that a four-inch refractor was barely able to enable an observer to view and hold Saturn's largest satellite, Titan, while stars below the second magnitude were hardly visible to the unaided eye. Last night, however, saw a marked improvement.

Sept. 21, 1908. ALBERT R. J. F. HASSARD,
Toronto, Canada.

Radiant Point for Meteors from Halley's Comet. A near approach of Halley's comet to the Earth on May 12, 1910 is indicated by the recent elements of Messrs. Cowell and Crommelin as given in the Monthly Notices of the R. A. S. for March 1908. Using the ephemeris of Dr. Smart in the same publication, and plotting his Δ's, I find by a graphical interpolation, that the distance of the comet from the Earth on the above date will be about 0.05 or about 4.6 million miles. It therefore seems probable that we may encounter some meteors. Accordingly I have calculated the radiant point for that date. As the eccentricity of the orbit of the comet does not differ greatly from unity and that of the Earth from zero, being respectively 0.96729 and 0.01677, I have made the calculation in three different ways, in order to note the difference in the results. In case 1, the actual eccentricities of both orbits were used in the computation, this being the correct method. In case 2, the eccentricity of the comet's orbit was assumed to be unity and of the Earth's orbit 0.01677, being the correct value of the latter. In case 3, the eccentricity of the comet's orbit was assumed to be unity and that of the Earth, zero.

The three results for the radiant point are given below in the above order.

CASE 1.
R. A. $22^h\ 42^m.9$ Dec. $+1°\ 18'$

CASE 2.
R. A. $22^h\ 44^m.9$ Dec. $+1°\ 29'$

CASE 3.
R. A. $22^h\ 45^m.9$ Dec. $+1°\ 32'$

It will be noticed that the three results do not differ greatly, the first, or correct value, differing from the last by three minutes of time and fourteen minutes of arc; while the result in the second case is intermediate between the other two.

O. C. WENDELL.

Harvard College Observatory.

Probable Nature of the Corona. The nature of the radiation of the inner corona has been supposed by some to be principally reflected solar radiation, by others principally due to the incandescence of particles heated by reason of their proximity to the Sun; by others principally luminescence, perhaps similar to the aurora; and by some as a combination of all these kinds of radiation.

A satisfactory theory of the corona must take cognizance of the following facts at least:

1. The color of the corona does not appear to change at varying distances from the limb of the Sun, and the transmissibility of its rays to the asphaltum screen is the same at 1′.5 and 4′.0 from the limb.

2. Its brightness is very small and falls off rapidly with increasing distance from the limb.

3. Its spectrum is mainly continuous near the limb, but shows dark Fraunhofer lines, more and more distinctly, at increasing distances therefrom. A few not very conspicuous bright spectral lines are present near the limb, and perhaps in the outer corona also.

4. Its light is polarized in the outer regions, but polarization grows less marked, and at length disappears near the limb.

5. Its brightness is almost, but not quite, as little transmissible to the asphaltum screen as that of the Sun itself; and far less so than the reflected brightness of ths Moon, but far more so than the reflected brightness of the sky.

6. Any kind of matter so near the Sun must be hot, and must reflect solar rays.

7. There is no evidence of high pressure in the corona.

The considerations (3), (5), and (7), taken together, are hard to satisfy. For if the inner corona were hot enough to give out a spectrum of incandescence satisfying (5), the matter composing it must be gaseous if it is like any matter we know of. Accordingly we should expect a bright line spectrum like that of the chromosphere if the inner corona shines chiefly by incandescence; and furthermore we should expect its rays to increase in transmissibility to the screen, and grow red to the eye, with increasing distance from the Sun.

If we may suppose that the temperature of the corona is everywhere low enough to allow solid or liquid particles to be formed, then all the specifications excepting (3) are easily satisfied by the hypothesis of a corona of reflection. Our knowledge is not sufficient to enable us to prove that the particles even of the inner corona would be too hot to be mainly liquid (that is to say about 3000° to 3500°). If they were all gaseous, the rays reflected would probably be richer than Sun rays in visible light, and this would be contrary to (5). May it not be that while a large proportion of the particles of the inner corona is gaseous, a considerable proportion is liquid or solid? Then

may not the light of the inner corona be mainly reflected, like that of the outer corona, but with the bright line spectrum of incandescent gases present in sufficient strength to nearly obliterate the dark Fraunhofer lines of the reflected Sun rays? The continuous spectrum of the incandescent solid and liquid particles present would tend to increase the transmissibility of the coronal brightness to the asphaltum screen; so that the opposite tendency of the diffuse reflection of the gaseous particles would be counteracted. At increasing distances from the limb we may suppose the particles would be cooler and mainly solid or liquid, so that incandescence would wane, and a dark line spectrum would gradually appear. Still the transmissibility and color would be still mainly reflected sunlight, and the particles now so large as not to enrich the proportion of the blue light, but rather slightly to decrease it.

As for the attractive hypothesis of the electrical discharge luminescence, like that of the aurora, one hesitates to recommend recourse to a source so little known. So far as known, too, this hypothesis like the others, has difficulty to reckon with the character of the photographic coronal spectrum.

The cause of the corona-brightness seems very difficult to decide in view of conflicting considerations; but in the judgment of the writer, the hypothesis that it is due to the reflection of ordinary Sun rays, but diluted by radiation of incandescence and perhaps also of luminescence, seems most tenable.

In conclusion it is a pleasure to acknowledge the great aid afforded by the Directors and staff of the Lick Observatory expedition; the conscientious and able work of my assistant Mr. Moore; the intelligent and faithful assistance rendered on the day of the eclipse by Chief Yeoman Chase of the *Annapolis*, and the uniformly cordial and courteous attentions of Governor Moore and the officers of the *Annapolis*, and of many others during the time when the expedition was in transit.

C. G. Abbot.

Lick Observatory Bulletin Number 132.

The Canals of Mars. During the summer Percival Lowell has published some interesting matter about the Canals of Mars in prominent magazines that received much attention. Some comments have been favorable and some unfavorable. The extreme views of the writers on either side have not gained the general support of astronomers as far as we know. The intention of the editors of this magazine has been to give the work of practical astronomers a fair presentation in its pages, and leave to the authors the responsibility of the opinions they offer as drawn from what they observe by the aid of the telescope. In this way we have given Mr. Lowell's work full attention because, as largely new matter it has deserved it. If he is not right in his conclusions he is responsible as a scientific man of ability and of remarkable devotion to his work.

In the same spirit we give below an extract from an address by Prof. Harold Jacoby of Columbia University which is a severe criticism on Mr. Lowell's work. We must not be considered as subscribing to these opinions about Martian observation:

"And now let me contrast with this another modern research that seems to illustrate the kind of scientific work sometimes undertaken in ignorance of the true test of value. I refer to the canals of Mars. By no conceivable possibility can this work convey to any one an impression of life everlasting

About it all is an air of unreality; one feels almost as if mankind would forget it before actually becoming aware of its existence. The strongest argument in favor of Martian canals is the intense desire of certain human beings to know other planets inhabited.

If I may be permitted to do so, I should like to turn aside here for a moment, and inquire what we mean by *seeing* a thing. What is the actual process? Light waves coming from the object under examination travel through the luminiferous ether, and finally impinge upon the outer surface of the eye, like surf breaking on an ocean shore. They are concentrated or brought to a focus by the lens in our eye, and produce some kind of an effect which we do not quite understand upon the rods and cones of the retina. This results in an impression being received by the brain, *via* the optic nerve. The brain in its turn does an unexplained something with this impression; what we think we see is equal to that which came through the eye and optic nerve plus what the brain does to it on the arrival at headquarters. It is this little *plus*, I fear that has helped to create the Martian canals and especially the intelligent engineers who built them. The human brain cannot distinguish between that which comes through the optic nerve, and that which the brain adds to it. The sum is what we seem to see.

Once started on the downward path to discovery, the rest is easy. We see what we desire and hope to see; do what we will we cannot prevent this; as Shakespeare says 'Increase of appetite had grown by what it fed on.'" —THE OBSERVATORY, September, 1908.

The Dispersion of Light in Space. A rather remarkable series of articles has been lately appearing in the *Comptes Rendus* by M. C. Nordmann, of Paris, and M. Tikoff, of Poulkova, relating to experiments made to determine whether light in its passage from a star to the Earth passes through a medium capable of refracting and dispersing it. The experiment consists in determining the light-curves for Algol variable stars for different regions of the spectrum. M. Nordmann examined Algol and λ Tauri, and found that the amplitude and form of the curve are the same for all regions of the spectrum in the case of both stars, but that the phases of the red image are in advance of the blue image, whilst the curves of variation of the green light have an intermediate position in this respect The observations show the following provisional results. The red rays from Algol reach us 16 minutes in advance of the violet rays, and for λ Tauri the advance of the red rays is about three times as great. M. Tikhoff at Poulkova has found similar results from RT Persei and W Ursæ Majoris; but if these experiments prove to be conclusive and the deductions from them well founded, we have to reverse some previous ideas, for it has hitherto been generally held that light of all colors travels through space with identical velocity. In 1882 some experiments by Fizeau's method were made by Messrs. Young and Forbes to prove this, and they arrived at the result that the velocity of the blue rays was about 1.8 per cent greater than that of the red, which is directly opposed to the result of the recent celestial experiments. It has often been pointed out that if such difference of velocity of light of different colors existed, the images of all stars would be lengthened into spectra, there would be a difference of color in a star immediately before and after occultation by the Moon, and similarly other peculiar phenomena would be observed which are not, so that it may be well not to consider this difference of velocity as yet proved.

In a later number of the *Comptes Rendus* (1908 June 15), M. Pierre Lebedew raises objections to this explanation of the observations. He says that the dispersion required by the observations is so great that if we assume it to exist in ordinary gaseous matter it would have an absorption so great that we should not be able to see the stars nor even the Sun. M. Lebedew suggests as another explanation that in the case of a star whose variation of light is caused by an occulting satellite, the observed effects would be caused if the satellite had an atmosphere which absorbed the light of the central star and did not surround the body symmetrically. M. Tikhoff replies to this in a later number.—THE OBSERVATORY, September, 1908.

Halley's Comet. Halley's comet, observed by Halley in 1682, the most sensational of the sky truants known to astronomers, is heading this way again on the visit which it makes every 75 years.

This news comes by way of mundane communication with the Yerkes observatory at Lake Geneva, where elaborate preparations are being made for photographing the visitor. The first plate will be exposed within two weeks and at close intervals thereafter throughout the fall, winter and spring of 1908-9.

The comet will not be visible to the naked eye, however, until well along in 1909, and will swoop into its perihelion, the point of its course closest to the Sun, about May 10, 1910.

Will it strike the earth and smash things up into bits? This has been a popular fear ever since about 12 B. C., but the authorities now assert that the earth is bound to squeeze by with several million miles to spare.

According to the French astronomers there is no danger whatever from Halley's comet and only one chance in 281,000,000 from all the rest of the comets put together.

In its youth Halley's comet, it is said, was a pretty wild young thing and might have made no end of trouble had it not passed too close one day or night, to the planet Neptune, whose mass was so huge in comparison that it exercised an instantaneous attraction for the comet.

They didn't collide, but the comet swerved out of its path, and from being a celestial go-as-you-please turned to chasing its own tail in a perfectly regular ellipse about the Sun, with Neptune exercising a salutary check when its flight tends to the erratic. It is a harnessed, though brilliant thing.

No other comet has had the influence on the human race which this one has had through the dread inspired by its brilliancy and sensational size.

More than one English historian blames Halley's comet for the weakness of the Anglo-Saxon resistance to the invasion of William the Conqueror in 1066. Halley's comet was then flaming nightly in the skies, adding, in the eyes of the superstitious Angles and Saxons, supernatural prestige for the Norman arms.

What is this comet? Is it a metallic mass thrown off from the Sun and whirling through space? Its mass is estimated as equal to that of an iron ball 150 miles in diameter spread out so thin that the total volume of the nucleus, or head of the comet, is much greater than that of the Earth, or, in fact, of any of the planets.

As the comet approaches the Sun the heat drives out metallic vapors of iron and magnesium. As the heat increases the hydrocarbons break up into

smoke or soot and trail behind. The bombardment of the Sun's rays on these minute soot particles lights them up to a silvery glow and also drives them out in a sweeping tail.—Detroit News.

The Great Red Spot on Jupiter. In number 4272 of the *Astronomische Nachrichten*, page 389, will be found an article by E. E. Barnard, of Yerkes Observatory, Williams Bay, Wisconsin, on The Great Red Spot of Jupiter. This article gives a brief account of its author's astronomical work on Jupiter during the last thirty years. Its aim is to show what influence the Red Spot has had on other prominent markings on the

GREAT RED SPOT ON JUPITER
Photographed by E. E. Barnard, May 26, 1908.
$13^h\ 52^m$ G. M. T.

planet's surface. The accompanying cut, also from the *Astronomische Nachrichten*, shows the position of the Great Red Spot in the midst of the great southern belt, as seen by Mr. Barnard 1908 May 26, by the aid of the 40-inch refractor of Yerkes Observatory. The first satellite is seen just going off the planet's surface at the left, the satellite's black shadow is also seen in the white belt below the spot.

Through the Depths of Space is a primer of Astronomy written by Hector Macpherson Jr., and published by William Blackwood and Sons of Edinburgh and London.

This young writer on astronomical subjects has already gained an enviable reputation as an author and an earnest student in dealing with themes that must interest the general reader. The field of modern astronomy is so broad and so varied that a well-read student in its best literature can find ample room and ample material for work of this kind. Mr. Macpherson has prepared under the name "Through the Depths of Space" a neat and scholarly monograph which he calls a primer of astronomy. Its eight plates presenting the Pleiades, Moon, Sun, Mars, Jupiter, Saturn, Daniel's Comet of 1907 and the North America Nebula in Cygnus are well chosen objects and what is almost equally important, they are from good half-tones and they are well printed.

The matter of the book is given in eight parts with titles: Our own planet; its place in nature; Moon; Sun: inner planets; outer planets, comets and me-

teors; stellar universe; in two chapters. It is written in paragraph form with heavy faced titles, so that reference to sub-heads is easy and natural, and the language used is simple, untechnical and direct.

The scientific spirit that characterizes this little book is of a high order. The author is not afraid to give an opinion on modern questions in astronomy, still in doubt, neither does he belittle or scoff at decided convictions of those holding opposing or radical views. Still more important, he can and does recognize, aptly and well, God as the great Author in all of the beautiful handiwork of the heavens. We think this is the secret of the young author's growing success and surprising ability as a writer.

The price of this primer is two English shillings.

Murray's Differential and Integral Calculus. It may be known to some readers, if not all, that Doctor Murray, the author of this new text is now Professor of Applied Mathematics in McGill University. It is also a fact that he has written text-books for schools and colleges on the Infinitesimal Calculus, plane and spherical Trigonometry and on Differential Equations. We have used some of these text-books and know of their value.

The new book before us is mainly made up from matter of his Infinitesimal Calculus, with additional matter relating to indeterminate forms, solid geometry and motion. We notice with special interest the articles that have been written in regard to velocity and acceleration. They will aid students in showing how to express, in mathematical language, the way these phenomena operate in nature, as determined so elegantly and so exactly by the principles of the Calculus.

Of course, this book is intended for beginners in the study of the Calculus; and so in its earlier parts treats of the elements of the branch quite fully and thoroughly. For example, the idea of a continuous function of a variable is set forth amply and in such varied way that a beginner ought to grasp it well from the first. The idea of continuity in the operation of a variable quantity is such a fundamental one in all the important parts of the Calculus, that the author has done well to emphasize it properly in the early pages of this book.

When the author takes up the work of differentiation, the notion of anti-differentiation is placed side by side with it, which is certainly well if not taken too far so as to divide the attention of the student while attempting to get a process that is entirely new to him in the kind of his thinking. A watchful teacher will easily guard this matter.

We notice with a little surprise that when this book takes up the subject of integration formally, it places the method of summation before that of the inverse process. It does not seem to us that this is the best order, because in the elementary work the inverse process is the more simple, being based on the thinking of what has gone before in differentiation and also on the anti-differentiation exercises already provided. There should be a fixed habit of doing in the mind of the student in the pure side of operation before he is asked to make an application of his new method of calculation to practical ends, unless he uses very simple illustrations. We do not think that the order the author has chosen makes a serious drawback for good. It is as he says a matter of choice in which good instructors differ in opinion.

On the whole this new book is a strong one. It is so well prepared that an earnest, ambitious student could study it without the aid of a teacher, and get along in it fairly well. It is also so extensive in the ground it covers and the long list of exercises and problems given, that it would take a good instructor with a class in college or technical school two full years to do it all as well as it should be done. This is our experience with classes in Calculus recently in preparing them for the best engineering schools in this country. That is not too much time to give to this very important part of a student's preparation if his mathematics is to mean something for him when he comes into the practical work of high grade engineering.

This new book contains 491 pages, its figures are many; they are well drawn; its printed page is easy for the eye, and its make-up is first class, such as its publishers, Messrs. Longmans, Greene & Co., always, so far as we know, send out.